TRANSACTIONS

OF

THE AMERICAN SOCIETY

OF

HEATING AND VENTILATING ENGINEERS

VOL. XVIII

EIGHTEENTH ANNUAL MEETING

NEW YORK, JANUARY 23-25, 1912

SUMMER MEETING

DETROIT, MICH., JULY 11-13, 1912

PUBLISHED BY THE SOCIETY
AT THE OFFICE OF THE SECRETARY
NEW YORK CITY

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CONTENTS.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

EIGHTEENTH ANNUAL MEETING.

New York City, N. Y., January 23, 24, 25, 1912.

PROCEEDINGS.

First Day—Afternoon Session.

(Tuesday, January 23, 1912.)

The meeting was called to order at 2.30 o'clock by President R. P. Bolton.

On motion the calling of the roll and the reading of the minutes were dispensed with.

Secretary W. W. Macon then read his report:

REPORT OF THE SECRETARY.

Your secretary for the Society year ending January 23 begs to submit the following report:

Under direction of the Board of Governors, quarters for transacting the Society's business were secured on the eighth floor of the Engineering Societies Building, 29 West Thirty-ninth Street, New York. Desks, chairs, rug, table and other office furnishings, including a typewriter, were purchased and an assistant for the secretary was engaged. The Secretary's office feels that it has been vigorous along the line of conducting correspondence to enlarge the membership of the Society and to induce the leaders in heating and ventilating engineering to contribute to its transactions. The effort is being made to keep the office open during business hours, and members visiting New

York are expected to make use of the office for receiving their mail and otherwise avail themselves of its facilities. The office is also open for committee meetings and its machinery may always be counted on to conduct committee correspondence.

Unquestionably much interest will lie in the financial showing here tabulated:

STATEMENT OF INCOME AND OUTGO.

Cash on hand, Jan. 26, 1911			$1,266.95	
Receipts.				
Dues		$3,488.96		
Initiation fees		1,070.00		
Sales of transactions, net—				
Volume 1	$12.50			
" 2	12.50			
" 3	12.50			
" 4	17.50			
" 5	17.50			
" 6	17.50			
" 7	12.50			
" 8	12.50			
" 9	20.00			
" 10	12.50			
" 11	16.25			
" 12	16.25			
" 13	16.25			
" 14	26.25			
" 15 ($75—$5 unpaid)	70.00			
" 16	3.75			
		296.25		
Badges, Pin—				
Solid gold	$51.00			
Plated	12.50			
		63.50		
Refund, Postoffice box		.40		
Interest on deposits		34.43		
			$4,953.54	
				$6,220.49
Disbursements.				
Transactions—				
Vol. 15 Editing	$100.00			
Extra cuts	40.82			
Printing, etc.	1,121.46			
		$1,262.28		
Vol. 16 Extra cuts		1.65		
Vol. 17 Engravings	$156.02			
Electros sold	79.77			
		76.25		
Meetings expense, 1911—				
Advance papers	$123.20			
Stenographer	294.00			
Meeting rooms, special printing, etc.	359.25			
	$776.45			
Contribution toward summer meeting	33.00			
		743.45		

Solid gold pin badges purchased		$30.00	
Directory of members, 1910		112.73	
Postage, express, etc.		174.14	
General administration—			
Assessments (rent) for office	$363.00		
Former Secretary, Dec., 1911, and Jan., 1911	310.84		
Committees, officers, etc.	150.09		
Ballots, certificates, etc.	150.25		
New furniture, typewriter, etc.	165.05		
Storage and insurance	41.96		
General printing	39.49		
Salaries	1,024.00		
Office stationery and supplies	136.64		
Telephone	24.05		
Exchange, misc. expenditures	17.21		
		2,422,58	
Total disbursements			$4,823.08
Cash on hand, Jan. 23, 1912—			
In hands of Treasurer		$1,266.91	
In U. S. mail to Treasurer		40.00	
In hands of Secretary		90.50	
Total cash			1,397.41
			$6,220.49

The figures are susceptible of considerable study, but it is desired for the present merely to indicate that the total expenses of the Society bear a high ratio to the individual membership. As shown by the accompanying table, the outgo is $1.83 more per member than is received from the member in dues. Additional expense will not, of course, increase directly with increase in membership, but instead increase is undoubtedly necessary to reduce the ratio. It is hoped at a later time to analyze the figures for the lessons they will undoubtedly teach.

PER CAPITA EXPENSE FOR FIVE YEARS

Year.	Mean Number of Members.	Total Expenses.	Expense per Member.
1907	301	$3,662.45	$12.20
1908	335	4,025.84	12.00
1909	357	4,687.41	13.13
1910	377	4,269.83	11.36
1911	405	4,793.08	11.83

The Secretary has an important announcement to make regarding papers. It is intended to send all papers to the members, together with a circular suggesting discussion by mail, say within thirty days, particularly with papers printed too late to reach the members before the meeting. The author will then be given

his prerogative of closing the discussion before the information is arranged for the printed volume of transactions.

A new directory of membership has not yet been issued, pending the settlement of the present movement looking to changes in the constitution. As the action taken at the annual meeting can be quickly settled by a mail ballot of the members, it is not expected that the membership will much longer be inconvenienced by not having the roster.

Accompanying tables will indicate the financial condition of the Society as regards dues and initiation fees accounts.

STATUS OF THE DUES ACCOUNT.

Cr.		
In arrears, including portion of class of candidates elected Dec., 1910	$960.00	
Paying members, Jan. 26, 1911, 382 at $10	3,820.00	
Class of candidates, June 12, 25 at $10	250.00	
Class of candidates, Dec. 1, 23 at $5	115.00	
Reinstated members, back dues	80.00	
Overpayment, account of foreign exchange	.28	
Class of candidates, Jan. 19, 1912, 13 at $10	130.00	
		$5,355.28
Dr.		
Written off by death and resignation	$37.50	
Written off by non-payment of dues	500.00	
Underpayments, account of foreign exchange	1.32	
Prepayment dues 1911 account in 1910	10.00	
Total dues received	3,488.96	
		4,037.78
Dues outstanding		$1,317.50

STATUS OF INITIATION FEES ACCOUNT.

Cr.			
In arrears, inc. portion class of candidates of Dec., 1910.	$410.00		
Class of candidates, June 12	375.00		
Class of candidates, Dec. 1	345.00		
Fee of advancement from junior grade	5.00		
Class of candidates, Jan. 19, 1912	185.00		
		$1,320.00	
Dr.			
Total initiation fees received		1,070.00	
Fees outstanding, inc. class of Jan. 19			$250.00
			$1,567.50

RECAPITULATION.

Total debit accounts of members	$1,575.00
Total credit accounts of members	7.50
	$1,567.50

Respectfully submitted,

W. W. MACON,

Secretary.

The Treasurer's report was ready by Secretary Macon.

REPORT OF THE TREASURER.

New York, January 23, 1912.

Balance on hand, January 23, 1911		$1,266.95
Cash Received:		
Dues, initiation fees, sale of proceedings, pins, etc.	$4,789.04	
Interest on deposits	34.43	
Electrotypes	67.19	
Redeemed protested check	28.54	
Refund, Post Office box	.40	4,919.60
		$6,186.55
Disbursements:		
J. J. Little & Ives Co.	$1,244.66	
W. M. Mackay, expense account	310.84	
W. M. Mackay, salary	50.00	
Clark & Gibby, Inc.	135.00	
United Engineering Society	482.10	
Schoen Printing Co.	381.93	
Arthur W. Kelly	294.00	
W. W. Macon, Secretary, salary	600.00	
W. W. Macon, expense account	689.23	
William Kent, editing proceedings	100.00	
John Geyer	43.25	
C. W. Bucknall	28.77	
J. D. Hoffman	29.29	
Williams Engraving Co.	90.30	
Typewriter Exchange	25.00	
Enders & Knopf	67.42	
J. W. Kelly Co.	30.24	
Metropolitan Fireproof Storage Warehouse Co.	37.50	
Oscar MacCullen	82.50	
Isadore Kohn	4.46	
J. Frick Jewelry Co.	30.00	
Breed, Abbott & Morgan	50.00	
R. D. Kimball Co.	34.00	
De-Fi Manufacturing Co.	5.90	
National Surety Co.	2.50	
Empire State Surety Co.	6.00	
R. W. Linen	1.00	
Allway & Hancox	2.25	
E. B. Bishop	10.00	
Stewart A. Jellett	8.50	
U. G. Scollay, Treasurer's account	6.80	
W. G. Snow	1.00	
Protested check	28.54	
Exchange on checks	4.66	
Heating and Ventilating Magazine	2.00	$4,919.64
Treasurer's balance on hand		$1,266.91

Respectfully submitted,

U. G. Scollay,
Treasurer.

On motion the report was received and referred to the Auditing Committee.

On request of the President, Vice-President Franklin assumed the chair. The President then read the report of the Board of Governors.

REPORT OF THE BOARD OF GOVERNORS.

The Board of Governors makes the following report of the activities of the Society since its organization January 26, 1911, immediately following the last annual meeting. The action of importance was the establishment of Society headquarters in the Engineering Societies Building, 29 W. Thirty-ninth Street, New York, in accordance with the recommendation of the annual meeting. It is believed that in becoming one of the associated engineering societies, assisting thereby in maintaining the identity of the engineering profession as an influential division of human endeavor, the Society has assisted itself and given it enlarged opportunity to help pay the debt it owes toward human progress.

That increased interest has been taken by the heating and ventilating engineers in the Society as an end toward mutual progress is indicated by a decided gain in membership, amounting to nearly 11 per cent. for the year. Interest among the members, it is believed, has also increased, as indicated by the accomplishments of the summer meeting held in Chicago, by the promise of the annual meeting of 1912, and in such details as an increasing vote on membership elections.

A specially noteworthy development was the organization of the New York Chapter, instituted by a call from the secretary to meet in the Society's office to discuss the feasibility of such a movement. The chapter was organized October 24, and its constitution and by-laws, subsequently submitted to the Board of Governors, was approved by a mail ballot by the Board and formally recognized at the Board meeting of January 23, 1912.

The financial affairs are dealt with in the reports of the treasurer and secretary and show that in spite of the unusual expenditures occasioned by taking quarters in the Engineering Societies Building and by purchasing furniture for these quarters, the per

capita expenditure has not been so large as in five recent years. It is important to call attention to the fact that the outgo per member is greater than the amount of dues per member and the Society is maintaining solvency through the receipt of initiation fees obtained by accessions to membership. While the next administration will not have the relatively heavy expenditure of the present on account of furnishings, the scale of operations set by the present meeting will mean a material increase in outgo, and a greater need of membership increase than ever. It follows, of course, that increase in numbers will make membership mutually advantageous to a greater degree on that account. It will tend to diminish the expenses per capita, and it will hasten the time when appropriations for committee investigations can be made in amounts commensurate with the importance of the work to be done.

The Board of Governors held seven stated meetings in the year. Its deliberations in detail will be found in the file of the Society records. Among the principal events was the summer meeting held in Chicago, July 6, 7 and 8, 1911. The following delegates were appointed to represent the Society at the third National Conservation Congress, held in Kansas City, Mo., September 25, 26 and 27: J. H. Kinealy, St. Louis, and B. C. Davis, J. H. Kitchen, J. M. Kent and A. H. DeLanney, all of Kansas City.

The details of the changes in membership are shown in the accompanying table. Three ballots in all were sent to the membership, May 13, October 31, and December 19. There were 29 candidates on the first ballot, of which number 3 failed of election; there were 25 candidates, all successful, on the second ballot, and 17 candidates on the third, 3 of which number failed of election. Of the number successful, 4 were voted for advancement from associate grade, making an increase in new members of 61. Two members were reinstated, making a gross increase of 63. The absolute loss was 23, as shown in the table, making a net gain of 40.

STATUS OF MEMBERSHIP

Honorary members				3
Members—				
Total number, January 26, 1911			347	
Accessions by election	50			
by re-instatement	2			
by advancement from associate grade	4			
by advancement from junior grade	1			
	—	57		
Losses by resignations	4			
by non-payment of dues	16			
by death	2			
	—	22		
Net increase		—	35	
Total number of members, Jan. 25, 1912			—	382
Associate Members—				
Total number, January 26, 1911			22	
Accessions by election		9		
Losses by advancement		4		
Net increase		—	5	
Total number of associate members			—	27
Junior Members—				
Total number, January 26, 1911			13	
Accessions by election		2		
Losses by advancement	1			
by non-payment of dues	1			
	—	2		
Net increase		—	0	
Total number of junior members			—	13
Total membership, January 25, 1912				425
Total membership, January 26, 1911				385
Net total increase				40
Increase, per cent.				10.5

The Society suffered a loss by death of two members: James R. Wade and Past-President James Mackay. In Mr. Mackay's untimely demise the loss was particularly heavy, owing to his re-

markable personality, his intimate knowledge of the Society's hopes and aspirations, his enthusiasm for its advancement, his wise counsel unselfishly and cheerfully given at all times, and his unimpeachable character, which won the unanimous, whole-souled admiration of even those merely acquainted with him. Few in the Society occupied as large a place as he did in it, and it is the unanimous recommendation of the Board that a resolution be adopted at the annual meeting to the end that a suitable testimonial of worth, esteem and affection may be placed on the Society's records to his memory and that an engrossed memorial may be offered to his family.

Of the other losses in membership, those who were dropped for non-payment of dues were offered every opportunity to express interest in the Society and failed to do so. Those who were honorably withdrawn from membership rolls by resignations which could be accepted were: Hugh S. Morrison, Richmond, Va., now deceased; Fred K. Houston, Rockford, Ill.; Wilhelm Dahlgren, Stockholm, Sweden; John C. Williams, New York City.

Finally, the Board is able to report that the volume of transactions for 1910 will shortly be issued and that a part of the transactions for 1911 are in the hands of the printer. It is expected that both volumes will be issued before the summer meeting.

Respectfully submitted for the Board by

REGINALD PELHAM BOLTON, Chairman.
W. W. MACON, Secretary.

Mr. Barron: I move that the report be received and placed on file and that the recommendation of the Board of Governors be approved by the meeting. (Seconded and carried.)

(President Bolton resumed the chair.)

The President: The next report is that of the Committee on Compulsory Legislation.

Secretary Macon: The chairman of the Committee on Compulsory Legislation is James D. Hoffman. Some months ago he sent in what was rather an elaborate undertaking to compile what might be regarded as a universally applicable ventilation

bill. He did not feel that it was complete. He has been trying to get the members to finish it. This morning I received a telegram from him saying: "Committee report not ready. Am sorry. Will try to have it in shape for the summer meeting. Will you kindly make a report of progress for me?"

The President: The Committee on Standards reports progress. Next is the report of Committee on Tests.

Mr. Donnelly made a brief report of progress of the Committee on Tests, and said that he had been conducting some tests on radiators, the results of which he would present at the evening session.

The President: The reports of the Committees on Air Leakage and Ventilation of the Closed Room, I understand from one of the members who is present, will have to be a report of progress. Next is the report of Local Chapters.

The report of the Illinois Chapter was read by Secretary Macon.

REPORT OF ILLINOIS CHAPTER. (Abstract.)

The January meeting of the Illinois Chapter was an open meeting held on January 9, in the rooms of the Western Society of Engineers, 98 Jackson boulevard, Chicago. At this meeting, resolutions on the death of Mr. William A. Green's son and the death of a member of the Society, Mr. William H. Bryan, were presented and adopted.

The various committees reported progress in all their work. Mr. B. Natkin, member of the Society, was elected to membership in the Illinois Chapter. The business meeting then adjourned to reassemble in the lecture room of the Western Society of Engineers and listened to a lecture by Mr. L. C. Soule on "Cast Iron Hot Blast Heaters," being an enlargement of his paper read at the St. Louis meeting. An interesting discussion followed.

The next meeting was held on February 13. A great deal of business was transacted relating to the Chapter's internal affairs.

At the meeting on March 13 the regular routine of business was transacted, after which the committee on Grate Proportions, consisting of Mr. Charles Newport and Mr. Robert Wid-

dicombe, made a report. They gave an account of a test of a house heating boiler's efficiency. From the discussion, it appeared that power boiler methods of testing cannot be applied to house heating boilers.

At the meeting on April 13 the resignation of Mr. George Mehring from the Ventilation Commission was regretfully accepted. Mr. Lewis, on behalf of the Ventilating Commission, reported that the committee was engaged in preparing several articles for publication, and was to coöperate with Dr. Evans in articles to be delivered before the Tuberculosis Convention in Denver, American Medical Association and Convention in Los Angeles and the American Education Association at San Francisco.

Applications from E. L. Hogan and F. W. Powers were accepted and approved. At this meeting, it was the president's painful duty to announce the necessity of Mr. Hale's resignation as he was leaving the jurisdiction of this Chapter. On behalf of the Society, he presented Mr. Hale with a remembrance in the form of a silver pitcher. For some time, the Chapter gave the meeting over to extending good wishes to Mr. Hale, and Mr. Lewis read an original poem in his honor.

Mr. Newport was announced as the successor to Mr. Hale for his unexpired time. Mr. Capron gave a most interesting talk, illustrated with lantern slides on his visit to the Panama canal.

The May meeting of the Society was a strictly social function, the Chapter having their ladies as guests. They attended the performance of the "Will-o'-the-Wisp," at the Studebaker theater, and afterwards adjourned to the Annex for an after-theater dinner and love feast.

The Society then adjourned until the annual business meeting which was held on October 9. This meeting was incomplete owing to the loss the Society felt in the death of Mr. James Mackay. President Patterson read his annual report. Secretary Newport and all officers reported in full. The following officers were elected for the ensuing year:

President, S. R. Lewis.
Vice-President, J. M. Stannard.
Secretary, W. L. Bronaugh.
Treasurer, August Kehm.

Board of Governors—N. L. Patterson, E. F. Capron, and G. M. Getschow.

Applications for active membership were received and accepted from A. S. Cameron, John D. Small, W. A. Cameron, and A. H. Schroth.

The next meeting of the Society was held on November 13, Mr. James A. Donnelly of New York being the guest of the Chapter, and he explained in detail the organization of the New York Chapter. Mr. Kehm gave an interesting talk on his European trip during the past summer, illustrated by photographs and post cards.

The next meeting of the Society was held December 11, and the application of Mr. E. Baker, Kewanee, Ill., was received and accepted. Mr. Lewis instructed the secretary to report on the progress that was being made in assisting the Health Department toward getting the increased appropriation for the Department of Ventilation. Resolutions in respect to the memory of James Mackay were approved.

Mr. de Joannis and his committee in charge of the meeting provided a most elaborate and complete report illustrated with mirrorscope pictures, on Hot Water Heating Auxiliary Appliances.

The meeting on January 8 was in charge of Mr. George Mehring, chairman of the Ventilation Commission. The Society had as its guests for the evening the following: H. W. Tomlinson, representing the American Institute of Architects; Meyer J. Sturm, representing the Chicago Architects' Business Club; J. R. Firman and G. W. Hubbard, engineers to D. H. Burnham & Co.; J. B. Dibelka and J. C. Harding, representing the Board of Education; Dr. W. A. Evans and J. W. Shepherd, of the Chicago Ventilation Commission; Prof. Owens, principal of the Teachers College; C. E. Beery, Board of Education, Rockford, Ill., and Dr. F. O. Tonney, of the municipal laboratories.

After dinner, the members present were taken in auto busses to the Teachers College, where a most interesting discussion was held on the work of the Ventilation Commission in the test plant in operation at this school. Discourses given by Mr. Shepherd of the Commission, Dr. Evans, Dr. Tonney, Mr. Tomlinson and Mr. Sturm showed the progress that was being

made in order to ascertain the proper method of ventilation of public school buildings.

We consider that the greatest thing that has been accomplished in the heating and ventilating profession in the past year has been the creation of a department for the inspection of heating and ventilating plants and attaching this to the Department of Health of the city of Chicago. This department consists of one engineer and five inspectors. It is the duty of the engineer to pass on all plans and specifications, and it is necessary to obtain his approval before a building permit can be issued in the city of Chicago. He is guided by the ordinances that were drawn up last year, which have already been reported on to the Society. These ordinances, while not perfect, are probably the strongest in existence, and now with the proper department for enforcing them we feel that we have accomplished a great deal, and that the great portion of the credit for the establishing of this department belongs to the Illinois Chapter.

Our membership is growing slowly, the attendance and interest are increasing at each meeting, and we feel confident that our sphere of usefulness will rapidly increase.

Respectfully submitted,

W. L. BRONAUGH, Secretary.

The President: It must be a matter of congratulation to all of us that this society has so active and progressive an institution as this Illinois Chapter has grown to be, and it reflects not only credit upon themselves but reflects credit upon the membership of the rest of the Society that they should have accomplished so practical a result as is recorded in this report. Without discussion the report will be ordered on file.

The report from the New York Chapter will be read by Mr. Joseph Graham, secretary.

REPORT OF NEW YORK CHAPTER.

The New York Chapter of this Society wishes to make the following report:

A preliminary meeting was held in the quarters of the So-

ciety in the Engineering Societies Building, 29 West Thirty-ninth street, New York, on the evening of Tuesday, October 10, by a number of New York members of the Society for the formation of a Chapter to be known as the New York Chapter of the American Society of Heating and Ventilating Engineers. At this meeting it was voted that the Chapter be formed and that the dues should be $5.00 per annum for members and associates, and $3.00 for junior members. Mr. W. M. Mackay was made temporary Chairman and Mr. Joseph Graham, temporary secretary. Committees were appointed on Constitution and By-Laws, and Nominations.

On October 24 the Chapter held a meeting in the Engineering Societies Building. A Constitution and By-Laws were adopted and the following officers unanimously elected for the ensuing year:

President, W. M. Mackay.

Vice-President, J. A. Donnelly.

Secretary, Joseph Graham.

Treasurer, Arthur Ritter.

Board of Governors—F. T. Chapman, H. T. Gates, F. K. Chew.

The monthly meeting of the Chapter was held on Tuesday, November 14. The following committee was appointed to act in connection with the committee of the Society to arrange for the entertainment at the annual meeting: D. D. Kimball, Chairman; M. F. Thomas; Conway Kiewitz; E. E. Fox; Thomas Barwick.

At this meeting the aims and purposes of the Chapter were discussed by the members. Mr. Barwick read a paper entitled, "By Advice of Our Consulting Engineer." This paper dealt with the relative efficiency of a city bureau and a private engineer with regard to work on city buildings. There was considerable discussion of this paper.

The Secretary presented a number of facts in regard to the ventilation of moving picture show places, showing the lack of ventilation laws for these show places throughout the country. The paper included several letters received from officials of the cities throughout the United States.

At the monthly meeting held December 12, a discussion of the necessity of ventilation for moving picture show places was

held. The President was instructed to appoint a committee of three who should prepare recommendations for the Chapter in regard to the ventilation of moving picture show places. The following committee was appointed: Frank T. Chapman, Chairman; W. W. Macon; Thomas Barwick.

The topic for discussion was "The Varying Efficiency of Radiation at Different Room and Outside Temperatures."

At the meeting on January 9, the Chapter's Committee on Arrangements for the annual meeting made its report.

The report of the committee to make recommendations in regard to the ventilation of moving picture show places was read and discussed.

The topic of the evening was "Temperature Regulation for Residence Heating," which was generally discussed.

While only permanently organized since October 24, the New York Chapter has a membership of 58 members, 2 honorary members, 3 associate members and 1 junior member, making a total membership of 64.

The Chapter has held three meetings which have demonstrated its value, all of which have been well attended.

At our monthly meetings we have had so far from 25 to 30 members present.

W. M. Mackay, President,
J. A. Donnelly, Vice-President,
Joseph Graham, Secretary,
Arthur Ritter, Treasurer.
Frank T. Chapman,
H. T. Gates,
F. K. Chew, Board of Governors.

New York, January 23, 1912.

The President: The chair would like to add to the report the fact that the committee on arrangements has worked in the most whole-souled and energetic manner and has devoted considerable time to meetings and has made all the arrangements for the entertainment of this convention.

We will now have the report of the Committee on Heating Guarantees, Mr. Mackay, Chairman.

The report was read by Mr. Mackay.

Mr. Barron: I move that the report be received and the Com-

mittee continued, and that the Board of Governors bring that as the last business before the meeting on Thursday. (Seconded and carried.)

The President: I will ask the following gentlemen if they will serve as tellers to count the votes for election of officers and report at the meeting this evening: H. W. Whitten, Arthur Ritter and George O'Hanlon.

Professor Kent is the Chairman of the Committee on Revision of Constitution. We are ready for that report.

Professor Kent: I can present it briefly, as it is already printed and members have the first proofs.*

REPORT OF THE COMMITTEE ON REVISION OF THE CONSTITUTION.

The Committee appointed at the last annual meeting to revise the Constitution of the Society has performed the labor assigned to it, and presents herewith the draft of a new Constitution for which it asks the approval of this meeting in order that it may be submitted to the entire membership for letter ballot.

The proposed new Constitution follows closely the old one both in form and in subject matter. Numerous minor changes have been made in the language, to make it more clear, and in the arrangement of some paragraphs and sections.

The proposed changes bring the Constitution in practical harmony with the Constitution of the larger engineering societies, and we strongly recommend its adoption.

Wm. Kent, Chairman.
Wm. G. Snow,
Frank K. Chew,
S. A. Jellett,
R. C. Carpenter.

Professor Kent: Under the present Constitution an amendment has to be proposed by at least three members and it then has to be passed by a majority of the members present in order to send it to letter ballot. While this report is signed by all the members of the Committee, Mr. Jellett has an amendment to propose which is not included in the Committee's report, and

* The Revised Constitution as finally adopted by letter ballot will be found elsewhere in this volume.

which he wishes inserted as an additional clause in the Constitution, and he may present it himself.

Mr. Jellett: The Chairman referred to an amendment which I intend to bring forward at this time, in view of the discussion at the last meeting. Here is the amendment which I propose to offer as an amendment to the Constitution:

"The Society reserves the right by a three-quarters vote of the members present at any executive session of the annual meeting to instruct its officers and committees on any matters affecting the Society's interests or policies, not specifically delegated to such officers or committees by the Constitution and By-Laws. Such instructions are to be carried out. Notice of such motion to instruct to be given at a session previous to the one in which the matter is to be discussed or acted upon."

Now the argument last year in the report of the Committee on Interpretation of the Constitution was that, the Society having elected its Board of Governors, it delegated to that Board not only all the powers that were in the Constitution and By-Laws but everything else; that they could not instruct the Board of Governors. That was the report of the Committee. But that did not meet with the unanimous view, by any means, of the members present at the time of the discussion, and as a result of that discussion this Committee on Revision of Constitution was appointed.

After some discussion of the report and of Mr. Jellett's amendment, Mr. Barron moved that its further discussion be postponed until the last session of the meeting. The motion was carried.

ADDRESS OF THE PRESIDENT.

The President: In order to make the presidential address something of a discussable nature and to present some material rather more interesting, I hope, than the average summarization of the events of the year, I have attempted on two occasions on which I have had the honor of presiding at the conventions of the Society, to present a subject which shall be general in its nature and yet personally and particularly interesting in character, and I know of none that is of more importance to all of us than this one, "The Use and Abuse of Fuel." (Reads paper.)

The President: I will now call upon Mr. Akimoff, of Philadelphia, to present his paper, "Heat Exchange Diagram: Its Application to the Theory of Air Washers."

Mr. Akimoff presented his paper in printed form with some remarks on the subject of humidity.

The President: Gentlemen, we certainly owe a vote of thanks to Mr. Akimoff for his preparing and describing this very interesting paper, which probably deserves much more discussion than we will be able to give it this afternoon. I shall take upon myself a practice followed by other societies of moving a formal vote of thanks to Mr. Akimoff, who is not a member of our Society, but I hope soon will be, for his interesting paper. It is moved and seconded that a vote of thanks be presented to Mr. Akimoff for his kindness in preparing and presenting this address.

The motion was put to a vote and carried.

The President: If there is no further discussion the Secretary will read the paper presented by Mr. H. C. Russell on "Drying Apparatus."

The paper was read by the Secretary and discussed by Messrs. Kent, Myrick, Wolfe, Donnelly, Jellett and President Bolton.

The President: The Secretary will announce the names of the new members elected during the year.

The list was read by Secretary Macon, as follows:

LIST OF NEW MEMBERS.

Edward E. Ashley, Jr.,	Member	Richard B. Hunt,	Member
Frank L. Busey,	"	B. W. Lewis,	"
D. G. Coates,	"	R. B. Mackinnon,	"
E. Q. Cole,	"	G. W. Martin,	"
Benjamin Cones,	"	R. S. Mayer,	"
Maxwell S. Cooley,	"	L. G. McCrum,	"
Joseph W. Curtis,	"	George McKnight,	"
P. L. Davis,	"	J. T. J. Mellon,	"
C. A. Dunham,	"	J. W. Muldowney,	"
J. H. Garrison,	"	W. J. Olvany,	"
A. W. Glessner,	"	O. M. Row,	"
W. F. Goodnow,	"	Richard Ruppel,	"
F. W. Gros Claude,	"	W. A. Schulte,	"
R. C. Hargreaves,	"	A. F. Sterrett,	"
H. M. Hart,	"	W. S. Timmis,	"
G. W. Hubbard,	"	E. J. Treat,	"

L. H. Drury,	Associate	J. E. Truitt,	Associate
C. J. Jackson,	"	George G. Schmidt,	Junior
H. B. McLelland,	"	Oliver E. Willis,	"
F. W. Smith,	"		

After some announcements by the Secretary the session adjourned.

First Day—Evening Session.

(Tuesday, January 23, 1912.)

The meeting was called to order at 8:00 o'clock p. m. by President Bolton.

The President: I will call upon one of the members of the Committee of Tellers of Election to make the report.

The report was read by Mr. Whitten.

REPORT OF THE TELLERS OF ELECTION.

The undersigned tellers appointed to count the votes for officers for the Society for the year 1912 have attended to their duty and beg leave to submit the following report.

Total number of votes cast, 194, of which 2 were blanks.

For President.

John R. Allen.......................... 101
August Kehm 91

For First Vice-President.

John F. Hale.......................... 97
Albert B. Franklin...................... 95

For Second Vice-President.

E. F. Capron.......................... 127
Ralph Collamore...................... 59

For Secretary.

W. W. Macon.......................... 179
Melvern F. Thomas.................... 13

For Treasurer.

James A. Donnelly	97
U. G. Scollay	94

For Board of Governors.

R. P. Bolton	160
J. D. Hoffman	136
S. R. Lewis	121
Wm. M. Mackay	110
D. D. Kimball	104
James H. Davis	91
N. S. Thompson	85
Geo. W. Knight	54
A. A. Cryer	49
Wm. McKiever	26

Respectfully submitted,
H. W. Whitten,
Arthur Ritter,
Geo O'Hanlon,
Tellers.

The President: In accordance with the report of the Tellers it is my duty to declare the following as the officers of this Society for the ensuing year:

Mr. John R. Allen, President;

Mr. John F. Hale, First Vice-President;

Mr. E. F. Capron, Second Vice-President;

Mr. W. W. Macon, Secretary;

Mr. James A. Donnelly, Treasurer;

Board of Governors: R. P. Bolton, J. D. Hoffman, S. R. Lewis, William M. Mackay and D. D. Kimball.

I should like, in the absence of our future President, Professor Allen, to have the opportunity of greeting and of introducing to you his First Vice-President, our respected and honored member, Mr. John F. Hale. Mr. Hale will favor us by advancing to the platform. (Mr. Hale comes to the platform.)

The President: Mr. Hale, on behalf of the Society I welcome

you as the future First Vice-President and will ask you to make amends to the audience.

Mr. Hale: Ladies and gentlemen: This, as is usual, is a great surprise. I had no idea that there was any possibility of my being elected to this office or being forced to act in the place of the President-elect, or I should probably have refused to have been put on the ticket. I thought that I would have a few years in which to watch the other officers and find out how the work was done. However, I shall be very glad to act in the place of President-elect Allen and hope that I will not make many mistakes. I thank you.

The President: We would like to hear a word from Mr. Macon. This is our new Secretary.

Mr. Macon briefly addressed the meeting.

The President: I should like now to have had the pleasure of hearing an equally modest address from our new Treasurer, and I have no doubt that we shall get it in the form most suited to his characteristics, of teaching us what he knows, for Mr. Donnelly has a very interesting paper, illustrated by some lantern slides, to present to us. After that we are hoping to hear an address by Dr. Tolman. That will be followed by an address on the growth of the skyscraper, and after that we have a moving picture show, which will conclude our evening's entertainment.

Mr. Donnelly then read his paper, which was illustrated by lantern slides, and was followed by Dr. Tolman, who gave an illustrated lecture on the means of prevention of accidents to workmen in industrial establishments.

Second Day—Afternoon Session.

Wednesday, January 24, 1912.

The meeting was called to order at 2:10 o'clock p. m. by President Bolton.

Mr. Conrad Meier read a paper on "Dust in Relation to Heating."

The President: We will now hear the report of the Com-

mittee on School Room Ventilation, which will be read by Mr. Cooper.

REPORT OF THE COMMITTEE ON SCHOOL ROOM VENTILATION.

The wide discussion which took place during the seventies as to the need for better sanitation of public buildings, including school houses, was the natural revival of the subject urged most earnestly for years by various writers, either as physicians or engineers, but which, perhaps, was set forth most clearly and interestingly from the standpoint of the educator by the work on "School Architecture," the fourth edition of which was published by its author, Dr. Henry Barnard, in 1850. In this book are found collated not only the opinions of physicians, but also of the engineers. (See Addendum A.) It is surprising to note what really slight additional knowledge of the subject of proper heating and ventilation has been contributed by the medical profession since that time. What has been done seems to be more in the study of certain branches of the subject.

In the meantime, the designing engineer has perfected appliances for easily creating and maintaining conditions to meet the requirements as laid down by the medical profession, which are, particularly, the delivery and removal of air, of a given quantity and temperature. Lately, however, the impression has grown that these standards or conditions are not wholly satisfactory, but the designing engineers, having met them, were loath to deliberately attack that which fell within the province of another profession.

This was the state of affairs at the time of our last annual convention when Dr. Luther Halsey Gulick addressed us. Perhaps we had before discussed among ourselves some of the things he told us, but his energetic and graphic presentation of the subject was most electrifying, coming, as it did, from such a well-known authority on medicine and child hygiene. This Society readily extended the aid and co-operation thus sought as to the further investigation of the subject of ventilation, and appointed committees to co-operate with the American School Hygiene Association, which had also taken up the matter. (See Addendum B.)

The work planned is based upon the belief that the requirements for ventilation should not only include temperature, air

movement and general purity of the air, but also that of humidity, in the effort to obtain positive evidence as to what effect its presence or absence may have upon the body or mind, and as to its relation to temperature.

At present legal authorities in several states set 70 deg. F. as a maximum temperature for the air content of a school room, and a variation in any two parts of not more than 3 deg., with an introduction of 30 cu. ft. of fresh air per pupil per minute, this without causing any unpleasant draughts. The amount of humidity is not provided for by any regulations, as far as we can find, and it is perhaps right here that the greatest deficiency exists in our present standards. According to the tests quoted by Dr. Gulick, humidity would appear to be one of the most important factors to be considered in relation to the health and comfort of the pupils.

Interest in the motion of the air within a room is of comparatively modern origin, and we do not yet understand thoroughly the principles which are involved. Experiments made upon subjects shut up for various periods of time in calorimeters, in which the air content, as well as all phenomena, are under observation and control, show that an increase in the amount of carbon dioxide present in the air is absolutely without apparent effect upon the mental and bodily comfort of the subjects of the experiment, provided the bodily temperature, with artificial cooling, be maintained at the normal.

For the purpose of inspection State authorities have insisted that the impurity of the air be ascertained by the determination of carbon dioxide content, and the limit to the amount which may be allowed in the air of a room is set at ten parts to 10,000. As a result of the experiments of which we have just spoken, considerable doubt has arisen as to the importance of the carbon dioxide test. If people are not affected by a larger amount of carbon dioxide, provided that the air is not allowed to become stagnant, perhaps there is no need of the present limitation, and all attention should be devoted to temperature, circulation and humidity.

The opinion of writers on ventilation and heating was well expressed by Billings when he stated in the early eighties, in his letters on ventilation and heating which were published in the then *Sanitary Engineer:* "Whenever a man takes the ground that

carbonic acid gas is the special impurity that has to be provided for, he demonstrates that he is a person who may be a very estimable gentleman, but whose opinions about ventilation should be received with great distrust."

An examination of the works of authorities on the composition of air leads to the conclusion that carbon dioxide is usually found in air which contains many other impurities more or less dangerous, for which there is no practical test for every day use. But as their proportions in the air, under normal school room conditions, vary much, as do the proportions of carbon dioxide, a determination of the latter, it is thought, will give a rough measure for probable general impurity. In any event, it must practically be used until such a time as the medical profession places at our disposal some easier or more efficient test for general impurities.

This Society, through the researches of its Committee on Standards, has consistently maintained that with our present knowledge it is impossible to set rigid standards for heating and ventilation. In this we are supported by Dr. Evans, who says: "There can be no single standard of efficiency of ventilation in the present state of our medical and bacteriological information."

That this matter of heating and ventilation of school rooms may be revised in a manner to meet the approval of scientific authorities, your committee on this subject informed the President of the American School Hygiene Association that it had been appointed with instructions to co-operate with the latter's committee on school-room ventilation.

It cannot be denied that the designing engineers of to-day are furnishing ventilation according to the standards given by the biologists and medical men, so far as any authorities are available. There is a lamentable lack, however, of available data of real value. However, if the ventilation provided is not satisfactory, it is due to the standards set up; and if these be wrong, it is the province of the biologist and physician to show that the physical condition of the persons affected would be better under definite changed conditions of temperature, humidity, air movement or purity, and the designing engineer will then supply improved heating and ventilating systems to meet these changed standards.

Weekly meetings have been held since September, to consider

the points involved. After numerous conferences the committee of the Hygiene Association has drawn up a standard form of test for use in all school buildings where right conditions prevail. (See Addendum C.) It has also carefully estimated the cost of making tests, in round numbers, $8,000, not including the cost of necessary alterations in heating plants.

Your committee has made arrangements for the carrying out of tests in one of the school buildings in the city of Boston. (See Addendum D.) These tests are now under way, and will be described in a report to be made at a later date by Mr. Eveleth, the member of our committee in direct charge of the tests. Arrangements are also being made with the school authorities of a town near Boston to have a test carried out in one of their school buildings.

In New York conferences have also been held as to the method of procedure in undertaking the proposed tests. It is planned to take one or two buildings of the letter H shape in which the two ends or halves are served with separate apparatus and place one part of the building under one condition and the other part of the building under another condition. For instance, half of the building is to be operated as usual, without humidification, while the other half is to be provided with a system of artificial humidification. In another building, half is to be left as usual, while the other will be submitted to a varying temperature never exceeding 70 deg., but for brief periods while the pupils are active, the temperature will be dropped to 50 deg. and then returned to 64, 66 or 68 deg., as may be determined. Other tests under consideration are, to try a less temperature in some of the buildings, and still others a diminished supply of air.

The greatest difficulty confronting the Committee in New York was the method of determining the results of these experiments. It was the consensus of opinion that the principal of the school, the teachers and even the janitor, should be kept in ignorance of the nature of the experiments under way, and that the results should be measured by the weight and health of the pupils as recorded by the visiting nurses, all absences due to ill health to be investigated as to their nature and cause. The effect of the different conditions was further to be observed through the records of the pupils' standing in their studies during the current year compared with last.

Money is not yet available for the employment of an observer to visit these school rooms constantly, and to take observations as to temperature, humidity, etc., and tabulate the conditions and results. The schools selected for the purpose of experiments were to be those in which all of the pupils were of approximately the same grade and coming from the homes of approximately the same conditions.

Much time has necessarily been consumed in preliminary work; this while preventing a report of results goes toward securing results that will be accepted by authorities.

FRANK IRVING COOPER,
CHARLES F. EVELETH,
HERBERT W. WHITTEN,
D. D. KIMBALL,
C. B. J. SNYDER.

ADDENDUM A.

The Plumber and Sanitary Engineer.

March 8, 1880.

Committee on Award in Sanitary Engineer School Competition.

A public school building should possess the following qualifications:

VI. The provisions for ventilation should be such as to provide for each person in a classroom not less than 30 cu. ft. of fresh air per minute, which amount must be introduced and thoroughly distributed without creating unpleasant draughts, or causing any two parts of the room to differ in temperature more than 2 deg. Fahr. or the maximum temperature to exceed 70 deg. The velocity of the incoming air should not exceed 2 ft. per second at any point where it is likely to strike on the person.

VII. The heating of the fresh air should be effected either by hot water or by low pressure steam.

Committee.
GEORGE B. POST,
JOHN S. BILLINGS,
JOHN D. PHILBRICK,
WILLIAM R. WARE,
C. R. AGNEW.

ADDENDUM B.

THE AMERICAN SCHOOL HYGIENE ASSOCIATION COMMITTEE ON HEATING AND VENTILATION.

Dr. Luther Halsey Gulick, Chairman, Director of the Department of Child Hygiene, Russell Sage Foundation.

Dr. T. S. Carrington, Asst. Sec., National Association for the Study and Prevention of Tuberculosis.

Dr. John W. Brannan, Head of the Hospital Board of the City of New York.

Dr. Henry Mitchell Smith, Practitioner of Medicine.

Dr. James H. McCurdy, Director Physical Course, International Y. M. C. A. Training School.

ADDENDUM C.

STANDARD TESTS FOR AIR CONDITIONING.

A. Conditions Under Which Tests Should Be Made.

1. For all tests there should be at least two class rooms, one in which the test can be made and one for control, on the same floor of a building, and having the same conditions; that is, the apartments should be as far as possible identical in size, exposure, amount of window surface, heating apparatus, etc.

2. The children in each set of conditions should be of the same grade and in the same general physical condition.

3. In so far as is possible the pupils and teacher should not know that they are the subject of investigation, but should be led to believe that a test of the heating apparatus is being carried on, so that no psychological factor will affect the results of tests.

4. The part of a building used as a control is to remain under the usual conditions normal to the school in which the test is made, the other room is to be used only for the tests. Records on both sides.

5. A record of each child's physical condition should be taken each day and recorded on a medical chart; also a daily record should be made in both school rooms covering everything that may affect the students, such as attendance and cause of absences, reasons for referring cases to the school nurses, any local infections discovered on children's bodies, and such school-room conditions as affect the comfort, health, or efficiency of the pupils. A blank suitable for making such records should be provided.

6. All medical records and charts should be kept by trained nurses.

7. A record should be made of the size of the rooms, length, width, and height, also cubic contents if irregular in shape, the number of students to each room, and the number of cubic feet of air space to each student.

8. Observations should be made in both sections at the same time, preferably at 9.30 a. m., 11.30 a. m., 1.30 p. m., and 2.30 p. m., and the records should be made by thermographs and hygrographs, and checked by thermometers and sling psychrometers. Two sets of thermographs and hygrographs

should be used, one set suspended one foot below the ceiling and one set at the height of the heads of the students when sitting at their desks.

9. The standard temperature for the control room is to be 68 deg., with humidity conditions usual to the building in which the test is made.

10. The instruction of students and length of hours is to be the same in both rooms each day and to follow the usual routine of the school in which the test takes place.

11. Mental tests are to be made by examinations once each week. Identical questions should be given pupils in both rooms on the same day and by the same examining teacher, who should not, if the test is oral, be the usual teacher of either class. The examinations are not to last over half an hour and the examination in one room should be followed directly by the examination in the other room.

12. Each test should cover a period of three months, January, February, and March.

B. Tests to Find the Effects of Temperature on School Children.

1. Test to be made in a building heated by a system of heating chambers and fans. The windows in the test room to be locked and sealed tightly. Temperature to be reduced each day one degree until 60 deg. is reached, average humidity of the air to be about 60 per cent.

2. Rooms heated by direct steam or hot-water radiators or stoves, the temperature is to be reduced one degree each day until 60 deg. is reached, humidity to be about 60 per cent. Room to be cooled by fresh air admitted from open windows and ventilators. Air to be humidified by evaporation pans over heating apparatus.

D. Tests to Find Effect of Fresh Air on School Children.

1. To obtain the results of flushing school rooms with fresh air. Rooms in which tests are made should have direct cross ventilation from windows thrown open both at top and bottom to their widest extent on opposite sides of building. Flushing should be made for a period of 3 minutes while the children are either out of the room or are exercising, the total time consumed being 5 minutes. Flushing to be done after each lesson period.

2. To obtain the results of open air class-room conditions without the effects produced by feeding and rest periods usual to open-air schools. Test room to be entirely open on one or more sides, and the children to be clothed as is usual in open-air schools.

ADDENDUM D.

December 29, 1911.

MR. FRANK IRVING COOPER, Chairman.

Dear Sir—

On behalf of the Committee on Heating and Ventilating of the American School Hygiene Association, I beg to say that we have examined with care the investigations proposed by your committee.

It seems to us that the points which you are endeavoring to secure information upon are fundamental and that the methods which you are adopting are judicious.

With best wishes for your work, we are,

Sincerely yours,

Committee on Heating and Ventilating.

(Signed) LUTHER H. GULICK,

Chairman.

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On motion the report of the Committee on School Room Ventilation was received and the Committee continued with a request to continue their labors during the ensuing year.

Mr. J. I. Lyle then read a paper on "Relative Humidity: Its Effect on Comfort and Health."

The paper by Mr. Percy Norton Evans on "Chemical Notes on Ventilation" was presented by title, in the absence of the author.

The President: I will now call for a presentation of the report of the work of the Chicago Ventilation Commission by the Secretary.

Secretary Macon: This is an informal report which was to be presented by Mr. Lewis, of Chicago, who was unable to be here on account of illness. (Reads report.)

REPORT OF WORK OF CHICAGO VENTILATION COMMISSION.

(*by S. R. Lewis*)

The Chicago Ventilation Commission was founded at the suggestion of Dr. W. A. Evans, primarily to study the present

progress of the art and to formulate adequate legislation for the enforcement of adequate ventilation. There seemed to be need of better understanding and coöperation between the health department and the ventilating engineering profession, especially as neither seemed quite to understand the other.

To start with, the best method of procedure seemed to be to introduce various resolutions, it did not matter much how radical these were, and by investigation and discussion either agree on these resolutions in turn, reject them, or investigate further. For instance, it was surprising to learn that even the question as to whether or not carbon dioxide was injurious to human beings in the quantities found in expired air was doubtful. We finally agreed that it was not specifically injurious in such quantities, and that since the proportions of carbon dioxide in air are easily to be determined, it was valuable as an index of other more subtle and less easily measured elements. We also were able to agree that the exact harmful or poisonous elements in expired air were not known as yet. The well-known "cabinet tests" made abroad and in this country about two years ago served to fortify these conclusions, as they seemed to indicate the following:

A man may live indefinitely in an air-tight room without inconvenience if the temperature and humidity are controlled within proper limits and if the air is agitated. They also showed that with improper temperature and humidity a man in an air-tight room breathing fresh outside air suffered practically as much inconvenience as he did when breathing the air in the air-tight room. This led to consideration of the resolution, to which we have agreed, that the condition of the air which touches the body, the aerial envelope must be a prime factor in ventilation. The temperature, humidity and purity of this air as well as that of the air inhaled must be properly adjusted.

Investigation of various types of heating and ventilating appliances indicates that nearly all of them are far from perfect in these considerations, and that the conclusions long ago arrived at by Dr. Evans are correct, in that drafts or currents in ventilating are desirable rather than otherwise. For instance, all methods of heating which continuously recirculate the air, as do direct radiators, stoves or furnaces, which have no outside air

supply, reduce the humidity to around 15 to 20 per cent. when somewhere around 70 per cent. is the normal outside average.

All systems of indirect heating, even with outside air supply, are also faulty as to moisture content, and have been found to average when in operation under 30 per cent. humidity. Direct radiators and stoves, heating the air which comes in contact with them to a relatively high temperature, induce local currents which rise from the heated surfaces and fall against the cool surfaces, such as outside walls and windows. Almost all present day systems of ventilation depend solely on dilution and difference in temperature for results, being influenced by these same local currents, as for instance, take a room heated by direct radiators and ventilated by a fan system delivering air at say 70 deg. The incoming air, being warmer than that in the room, rises to the ceiling and enters the cycle of circulation formed by the radiators, mixing with the air already there. It falls down the cold glass surfaces, strikes the rising currents from the radiator and stays pretty well out against the outside walls, while the interior of the room gets no fresh air at all at the breathing line, and has cool currents along the floor seeking the foul air exit. The air which leaves by the foul air exit is just as fresh as any other air in the room, but happens to be cooler, hence is rejected.

Now, in the same room let us suppose that the incoming air is cooler than that in the room. It does not rise to the ceiling, being heavier than the air at that point, nor does it go to the windows since there is already a down current of cool air there. It drops right down to its own temperature level, and if the air at the floor is warmer than it is, it describes a beautiful curve right back bodily to the outlet opening at the floor, leaving the room little if any better for its presence.

Let us suppose there are no radiators in the room but that the incoming air supplies the heat required, as well as the ventilation. When the incoming air is warmer than the air in the room it keeps above the room air, gradually forcing it down in fairly level strata, and accomplishes reasonably good ventilation undisturbed by the rising currents from the radiators, except that every cool surface, such as glass and outer wall, is causing a miniature Niagara of cooling fresh unbreathed air to drop to the floor, across which it hurries to the outlet, without

having accomplished its purpose, and the occupied center of the room gets very little fresh air, and no desired and needed currents.

When the incoming air is cooler than that in the room, the same short circuiting above described results. Were we able to build buildings so perfectly insulated that there would be no surfaces any cooler than others we would need no direct radiation, and could ventilate quite satisfactorily with properly humidified air on the downward principle. However, in such perfectly insulated buildings we could ventilate by cross currents too, as the incoming air would be at the room temperature. As it is, using the dilution principle, whether downward or across, the conditions are somewhat like washing a bottle which holds red ink by introducing clear water. The red color will persist while enough clear water runs through to change the contents very many times. It appears that we need some method of ventilation which will bodily change the air in a room, positively, regardless of local circulation such as introduced by stoves, radiators and cold windows. Only when we have such a method will we get real ventilation, such as we get when we open the windows and let the summer breezes push across through every part of a room, washing, as one may say, every surface, and driving away all pollution. Air is the most persistent, elastic, clinging, baffling commodity we have to deal with.

That the Chicago Ventilation Commission might have full opportunity to study and experiment the board of education has appropriated funds and given the use of a room in one of the schools for experimental purposes.

The upward method of circulation, with individual controllable nozzles blowing the air against and around the bodies of the occupants, is now being thoroughly tested. We wanted to know why, if the air is conditioned properly as to temperature and humidity, it should be necessary to deliver say 1,800 cu. ft. per hour per person when his hourly lung capacity is only about 16 cu. ft. We want to know why, if the air is introduced at the proper temperature around the body of each occupant, it should be necessary to have any other means of heating a room. We wanted to know what that proper temperature is. We wanted to know what the proper humidity is. Our judgment is that 60 deg. temperature, say 500 cu. ft.

of air per hour, and a humidity of 50 per cent will give the best results.

We are keeping a close record of attendance, health, efficiency, and comfort of the occupants of the experimental room. The air rises to the ceiling where it is removed. The heat given off by a human body is sufficient to cause an appreciable rising air current. The heat given off by a roomful of bodies is sufficient very appreciably to raise the temperature of that room. If we have the floors, walls, furniture, etc., of a room warm before occupancy, it will be unnecessary to introduce much heat after the room is occupied. That is, the incoming air need not be much warmer than the desired temperature of the room. This outlines the work of the Chicago Ventilation Commission as to the ventilation of rooms occupied by a number of people in sedentary pursuits. It applies to schools, theaters, factories, churches, etc., where the people are not constantly moving about. It covers the field in which most effort has so far been made to secure ventilation. Our investigations along the line of stores have not been so thorough. We agreed as a matter of public policy to discountenance the use of sub-basement spaces for selling, on account of the following partial reasons:

No perfect system of ventilation has so far been shown to be perfect as compared with God's sunshine, wind and rain. No space which is not at some time each day touched by daylight, and which cannot be washed by natural fresh breezes, is fit for human occupancy. The temperature and humidity of such places cannot approximate outside conditions except when elaborate mechanical appliances, including artificial refrigeration, are employed. These appliances may at the wish of the owner or by carelessness or accident be out of service and the occupants will then be unprotected.

The use of underground spaces tends still further to congest the downtown parts of cities, in an artificial and unhealthy way. Until the time comes when the government of cities is so perfectly developed as to have the means positively of enforcing its ordinances and insuring that air conditioning devices be operated properly every day, we believe it unwise to permit the use of underground selling or manufacturing floors. We believe that the purity of air is as important as the purity of water or food and that it requires the same supervision and legislation.

The Chicago Ventilation Commission has had a part in the work of promoting open air schools and has from time to time given the work along this line in Chicago much deserved publicity. Through our efforts and influence the book "Open Air Crusaders" has gained a share of its phenomenal circulation. It is evident that the new ventilation must be a result of the coöperation of the hygienists, the architects and the engineers. New methods of flue construction and insulation of walls and glass are apparently necessary. With the ability to use cross ventilation, from side to side or end to end, of rooms, uninfluenced by local vertical currents, for sparsely inhabited rooms, or rooms in which the people are moving about, we can produce real results. With upward ventilation, introduced above the floor away from the floor dirt, from underfloor ducts, and ceiling outlets in thickly inhabited rooms we can produce real results. The saving in cost of operation due to the much smaller quantities of air needed over the present dilution system will go far to offset the additional cost of building construction.

Mr. Kimball presented a paper on "Ventilation Problems."

A discussion of the above named papers and reports then took place which was participated in by several invited guests of the medical profession, including Dr. W. Gilman Thompson, of the Medical College of the City of New York; Dr. C.-E. A. Winslow, of the College of the City of New York; Dr. James H. McCurdy, of the International Y. M. C. A. Training School, Springfield, Mass.; Dr. C. Ward Crampton, Director of Physical Training, New York; Dr. Thomas S. Carrington, Assistant Secretary of the National Tuberculosis Association; Dr. Luther H. Gulick, of the Department of Child Hygiene, of the Russell Sage Foundation; Mrs. S. S. Wise, New York; Dr. Henry Mitchell Smith, New York; Mr. Frederic Bass, Engineer of the State Board of Health, Minnesota; Mr. Frank G. McCann, Mr. H. Thurston Owens, and Mr. J. W. H. Myrick.

Secretary Macon: I am very much interested in what has been said and the papers that have been read, but particularly I wish to ask that a special invitation be extended to Dr. McCurdy to report at the next meeting the result of his experiments at his experimental station.

The motion was seconded, put to a vote and carried.

On motion the meeting adjourned till Thursday morning.

Third Day—Morning Session.

(Thursday, January 25, 1912.)

The meeting was called to order at 10:45 o'clock a. m. by President Bolton.

The President: Gentlemen: I wish, on behalf of the Board of Governors, to draw attention to a fact that was not recorded in their report for the past year, the death of Prof. Warren S. Johnson, by which this Society has lost a valued member; and I will on behalf of the Board of Governors offer a resolution recording our regret at his death and ordering that this expression of regret be spread upon the records of the Society, if that resolution finds a seconder.

The motion was seconded by Mr. Chew, put to a vote and carried.

Mr. D. S. Boydon, of Boston, read a paper on "Steam Heating Large Department Stores; Its Relation to Their Electrical Requirements." It was discussed by President Bolton.

Mr. Ira N. Evans presented a paper on "Vacuum Hot Water Heating by Forced Circulation."

The Secretary then presented a paper by Mr. J. J. Wilson, on "Auxiliaries for Pressure Systems of Hot Water Heating." It was discussed by President Bolton and Messrs. Donnelly and Whitten.

The President: Our next paper is one of particular interest, although I believe it has not been printed and issued to the members, because it is presented by our good friend Mr. Beaurrienne, who has come from the other side of the Atlantic to tell us what he has to say upon the interesting subject of "Steam Heating from the Receiver of the Compound Engine," upon which we all have much to learn.

Mr. Beaurrienne read the paper.

On motion of Mr. Donnelly a vote of thanks was tendered to Mr. Beaurrienne for his interesting and instructive paper. (As the paper was of a character demanding study before one could discuss it, and as it had not been distributed prior to the meeting, it was decided to withhold it for the 1913 proceedings to incorporate with it such discussion as might ensue.)

Mr. A. M. Feldman read a paper on "Ventilating of a Steam Laundry."

The report of the Special Committee on Standards for Flange Fittings was read by Mr. Kent.

REPORT OF SPECIAL COMMITTEE ON STANDARDS FOR FLANGED FITTINGS AND FLANGES.

The President submitted to the Committee a letter addressed to the Society dated January 24, 1912, signed by the Secretary of the National Association of Master Steam and Hot-Water Fitters and the Secretary of the American Society of Mechanical Engineers, as follows:

"Herewith please find copy of the 1912 U. S. Standard Schedule of Standard Weight and Extra Heavy Flanged Fittings and Flanges, which has been recommended by a Joint Committee of the National Association of Master Steam and Hot-Water Fitters and The American Society of Mechanical Engineers.

"This is placed in your possession in order that your Society may take advantage of the opportunity to concur in the action of the above named Joint Committee and adopt the Schedule in its entirety."

Your Committee has conferred with the Secretary of the National Association of Master Steam and Hot-Water Fitters and the Secretary of The American Society of Mechanical Engineers, and has examined proofs of the 1912 U. S. Standard Schedule of Standard Weight and Extra Heavy Flanged Fittings and Flanges which was adopted by the Joint Committee of the two societies on October 25, 1911, and after such conference and examination reports that it approves of the Standard Schedule of Flanged Fittings and Flanges submitted and recommends that the members of this Society use the schedule in their designs.

Your Committee understands that the new Schedule of Standard Weight and Extra Heavy Flanged Fittings and Flanges will be printed in the Official Bulletin of the National Association of Master Steam and Hot-Water Fitters, February issue, and The Journal of The American Society of Mechanical

Engineers, February issue, and therefore suggests that the Secretary of each society be promptly notified that the Special Committee of this Society has endorsed the schedule, so that notice to that effect may be inserted in their publications if they so desire.

Your Committee has not had time or opportunity to make any extended examination into the details of the standards adopted and is therefore basing its action and endorsement in the matter upon the fact that the Joint Committee of the two societies most interested has adopted the schedule after a long and careful study of the proportions best suited to the requirements of the profession and trade.

Respectfully submitted,

Wm. Kent,
P. H. Seward,
W. M. Mackay,
John F. Hale,
A. M. Feldman,
Committee.

On motion the report was accepted, and the Secretary directed to notify the secretaries of the two other societies whose committees coöperated in framing the report of this action.

On motion the session adjourned to two o'clock.

Third Day—Afternoon Session.

(Thursday, January 25, 1912.)

The meeting was called to order at 2:10 o'clock p. m. by President Bolton.

Prof. Frank L. Busey read a paper on "Heat Transmission with Indirect Radiation." It was discussed by Messrs. Kent, Ingalls and Barron.

On motion of Mr. Barron a vote of thanks was extended to Mr. Busey for the contribution of his valuable paper.

The President: I will now invite Mr. Norman A. Hill to give us a paper which he has prepared on "The Efficiency of the

Labor Element in the Heating Industry." Mr. Hill then presented his paper, which was discussed by Messrs. Barron, Feldman and Bolton.

The report of the Committee on Revision of the Constitution was then taken up.

Professor Kent: The Committee on Constitution and By-Laws presents a unanimous report in favor of the adoption of this revised Constitution.

I move that this proposed amendment, that is the revised Constitution, be approved by a majority of the members present, and I will bring up later the question of the amendment which has been proposed by Mr. Jellett. I would ask in voting that it be by a rising vote, so we can count the members here. (Seconded.)

The President: This is a formal resolution, under the terms of our Constitution, which will enable the work of the Committee on the Constitution to be brought before the members in due course, so that their opinion may be obtained thereon by letter ballot, so therefore I think the best expression of opinion of our members will be found in these ballots. I do not know that any discussion is needed here on the general subject, but if any member feels that he has anything affecting his suggestion we will hear from him.

The proposed Constitution was discussed by Messrs. Barron, Chew and Donnelly. Some minor changes were suggested, and Messrs. Kent, Chew and Snow, a majority of the Committee, retired in order to incorporate them in the report.

A paper was then read by Mr. Teran, on "Heating a Swimming Pool." It was discussed by President Bolton and Messrs. Feldman, Weinshank, Mackay, Franklin and Mobley.

The President: We will now return to the report of the Committee on Revision of Constitution.

Professor Kent: We have now the revised report to submit, with Mr. Bishop's amendment making the Secretary a member of the Society. We have also accepted Mr. Donnelly's amendment making Roberts' Rules of Order the rule for meetings instead of Cushing's Manual. We have not accepted Mr. Barron's amendment making the Secretary an elective officer of the Society. In this form we present the report.

The President: The motion is to approve this report of the

Committee on Revision of Constitution and direct the Secretary to send each member a copy of it with a letter ballot. It will require a two-thirds vote by letter ballot to be adopted.

The report was approved by a rising vote.

Mr. Chew: Now, Mr. President, possibly I am in order with an amendment which Mr. Jellett presented the other afternoon. I hold in my hand the authorized signatures of Mr. Jellett, Mr. Wolf and myself. To make that amendment come properly before the body we offer it at this time.

Mr. Jellett's amendment was read by Professor Kent, as follows:

"The Society reserves the right by a three-quarters vote of the members present at any executive session of the annual meeting to instruct its officers and committees on any matters affecting the Society's interests or policies, not specifically delegated to such officers or committees by the Constitution and By-Laws. Such instructions are to be carried out. Notice of such motion to instruct to be given at a session previous to the one in which the matter is to be discussed or acted upon."

The amendment was further discussed by Mr. Chew, and was opposed by Messrs. Bishop, Mackay, Ingalls, Kent and Snow, and favored by Messrs. Donnelly, Barron and Myrick.

The President: Those in favor of adopting this amendment will signify it by standing up. The Secretary will please count. Those contrary minded will please stand up. The Secretary will announce the vote.

Secretary Macon: Total number of votes cast 34. There were affirmative votes amounting to 20.

The President: The question now is really as to whether it shall go to the members.

The question was called for.

The President: Now, those in favor of this amendment being sent to the members to be voted upon please stand up.

(The Secretary announced a vote of 23.)

The President: Those contrary minded will please rise. I think the ayes undoubtedly have it.

The President: That important matter having been dealt with, at the close of our business we will pass by title the last one of the papers left, a small contribution of my own, "On the Definition of the Unit of Heat," which was really only in-

tended to have been a contribution of a topic for discussion. The four subjects set down for discussion in the case of time being available for the purpose may well be passed over to our summer session. And I should like to welcome to the chair before we part the representative of your newly elected President, who is, I believe, to act in his place during the entire period of his term of office.

If Mr. Hale will now come to the chair I shall be very glad to welcome him and resign into his hands the very interesting and pleasant duties which have occupied me during the last twelve months. And in so doing, gentlemen, representing the Society, I wish to thank you for all the support that I have had, for the interest that has been exhibited in the growth of the Society, and again to express my sense of appreciation of the direct help and attention that I have received from the other officers, particularly from the members of the Board of Governors, from our worthy Treasurer, from our still more worthy Secretary, and in particular from our past Secretary, Mr. William M. Mackay. Gentlemen, I thank you and bid you farewell.

Vice-President Hale (on assuming chair): Gentlemen, it is very gratifying to me this evening to discover that the business is almost completed. Because I had little warning of the responsibility of coming into this position. And although I hope to represent President-elect Allen in a creditable way, I trust that you will bear with me if I make any mistakes, and I will try not to make any more than is necessary.

Mr. Secretary, are there any other matters to come before the meeting?

Secretary Macon: Mr. President, I want to just formally recognize the receipt of the report of the Special Committee on Factory Ventilation Legislation for New York State. This was a sub-committee of our general committee on the general subject of compulsory legislation; and in view of the President's report on that subject this did not come up at that time. But I think we might formally receive it without reading.

Vice-President Hale: Gentlemen, you have heard the suggestion of the Secretary as to this report. Have you any suggestions to make?

On motion it was ordered received.

REPORT OF THE COMMITTEE ON FACTORY VENTILATION LEGISLATION.

The Special Committee on Factory Ventilation Legislation begs to offer the following report.

Previous to the convening of the Legislature of the State for the year 1911, this Committee held several conferences and discussed the subject of legislation requiring ventilation of factories in this State. It was determined that we should introduce a bill embodying our views, after conference with the American Society for the Advancement of Labor Legislation, the Commissioner of Labor, the Real Estate interests, and other interested parties.

A bill was outlined embodying our views, which was submitted to a conference of the above interested parties. This was referred to a sub-committee, consisting of Mr. Sherman, former Labor Commissioner; Mr. Williams, present Commissioner of Labor and the Chairman of this Committee.

After several conferences a bill was agreed upon, which was submitted to the General Committee and approved by them. A copy of this bill is attached hereto. It was essentially a compromise and failed to give entire satisfaction to any one of the parties concerned. It was deemed wise that the bill should be introduced by the American Society for the Advancement of Labor Legislation, because it was thought that it would thus seem less a partisan measure.

It should be pointed out in this connection that the greatest difficulty encountered by the Committee was the confusion prevailing in the minds of the members of the different organizations interested, as to what was essential to proper factory ventilation and how it should be measured. The Commissioner of Labor was again strenuous in his advocacy of the CO_2 method of determining the standard of ventilation. Prof. Winslow felt that the question of relative humidity should not be neglected; others felt that the temperature should be definitely stated and fixed within certain limits. Your Committee felt that some of these considerations were valuable enough but were confusing and in advance of the times, therefore, that present conditions would be immeasurably improved if a certain volume of air was specified by our bill.

It should be recognized that such difficulties are but a part of the signs of the times, and that the doubt or unrest applying in this case is similarly applicable to the question of ventilation of schools, hospitals, etc. It would seem, therefore, most important, as an aid to the securing of ventilation legislation, that these mooted points on ventilation should be as speedily as possible cleared up.

The bill, as finally agreed upon, was introduced into the Legislature, but the last session was not conducive to the passage of bills other than those essential, or interesting to the politicians in control. Because of this fact and possibly the additional fact that no one party interested in the bill believed in it sufficiently to put a great deal of effort into the matter, the bill failed of passage.

Your committee feels that a simple bill requiring a certain volume of air supplied to all factories should be passed as a means of improving the conditions in factory lofts, which certainly require remedying. We would suggest that a new committee be appointed with instructions to introduce such bill early in the legislative session, and it would be our suggestion that this be done without reference to any of the parties heretofore consulted. It is believed that the chances of the passage of such bill are better than during the past two years.

To accomplish this result will require a reasonable appropriation on the part of the Society for printing, postage, traveling expenses and legal fees, the amount of which would probably be $150.00 to $200.00.

The Committee desires especially to express its appreciation of the very great assistance rendered by Messrs. L. R. Hoff and P. T. Baker of the H. W. Johns-Manville Company, all of which was given liberally and without expense to the Society.

Respectfully submitted,

D. D. KIMBALL, Chairman.

President-elect Hale: I am told that Mr. Cooper has a resolution which he wishes to offer.

Mr. Cooper: Mr. President and fellow members: I would like to make this motion on behalf of the Committee on Heating and Ventilating School Rooms:

"Resolved, that the thanks of this Society be voted to Mr.

Charles F. Eveleth for his interest and zeal in securing the consent of the Boston school authorities to carry on experiments in heating and ventilating school rooms in the City of Boston; and further; that the Secretary be instructed to send Mr. Eveleth a copy of this resolution."

(The motion was seconded, put to a vote and carried.)

On motion the meeting was adjourned.

LIST OF MEMBERS AND GUESTS PRESENT AT THE EIGHTEENTH ANNUAL MEETING, JANUARY, 1912.

New York, January 23, 1912.

MEMBERS.

Addams, Homer
Andrus, N. P.
Armagnac, A. S.
Armstrong, C. G.
Ashley, E. E., Jr.
Barron, Hugh J.
Barwick, Thos.
Bishop, C. R.
Blackman, A. O.
Bolton, R. P.
Boyden, D. S.
Bradbury, C. R.
Bradley, J. T.
Busey, F. L.
Cameron, W. A.
Chapman, F. T.
Chew, F. K.
Clark, W. D.
Cooper, F. I.
Cryer, A. A.
Cryer, T. B.
Culbert, W. G.
Davis, B. C.
Davis, J. H.
Denny, E. B.
Doherty, P. C.
Donnelly, J. A.
Dornheim, G. A.
Driscoll, W. H.
Edgar, A. C.
England, G. B.
Farnham, G. D.
Febrey, E. J.
Feldman, A. M.
Fenstermaker, S. E.
Forgee, F. A.
Fox, E. E.
Franklin, A. B.
Gardner, S. F.
Geiser, Harry
Gombers, H. B.
Goodnow, W. F.
Graham, Jos.
Greey, G. V.
Hale, John F.
Hankin, Richard
Hargreaves, R. C.
Haslett, C. A.
Hill, N. A.
Hinkle, E. C.
Hoffman, P. A.
Hunt, R. B.
Ingalls, F. D. B.
Jellett, S. A.
Joannis, Harry de
Kehm, August
Kent, William
Kiewitz, Conway
Kimball, D. D.
Knight, G. W.
Lemmey, Robert
Lisk, J. P.
Lyle, J. I.
Lynd, R. E.
Mackay, W. M.
Macon, W. W.
Maginn, P. F.
Mallory, H. C.
Mappett, A. S.
Marshall, A. B.
Martin, G. W.
McCann, F. G.
McKiever, W. H.
Miller, M. P.
Mobley, E. S.
Monash, M. E.
Moore, J. A.
Morrison, Chas.
Munroe, E. K.
Myrick, J. W. H.
O'Hanlon, Geo.
Paul, A. G.
Pearce, C. E.
Polglase, D. E.
Ritchie, William
Ritter, Arthur
Robertson, G. A.
Schmidt, G. G.
Schroth, A. H.
Scollay, W. G.
Scott, C. E.
Seward, P. H.
Shanklin, J. R.
Sherman, L. B.
Smallman, W. T.
Snow, W. G.
Snyder, C. B. J.
Stangland, B. F.
Stannard, J. M.
Stockwell, W. R.
Tallman, D. S.
Teran, C.

Thomas, M. F.
Timmis, W. S.
Tobin, G. J.
Treat, E. J.
Vrooman, W. C.
Webster, Warren
Weinshank, Theo.
Welsh, H. S.
West, Perry
Whitten, H. W.
Williams, H. L.
Willis, O. E.
Wilson, F. A.
Wolfe, W. F.

GUESTS.

Abercrombe, J. H.
Affleck, G. B.
Akimoff, N. W.
Baldwin, W. J., Jr.
Barnes, D. W.
Beakes, F. M.
Beatty, H. L.
Beaurrienne, Auguste
Bergen, G. L.
Bloom, S. C.
Bottsford, E. D.
Braemer, W. J.
Brannan, J. W.
Brightman, H. M.
Bushnell, H. C.
Campbell, Thos.
Carrington, T. S.
Cheshire, Wright
Claypool, R. L.
Colbert, W. F.
Collins, Hubert E.
Commer, F. M.
Corwin, E. H. L.
Crampton, C. W.
Darts, J. A.
Day, S. D.
Dickinson, W. S.
Driggs, A. A.
Durand, W. L.
Ebeling, F. O.
Edwards, G. W.
Evans, H. C.
Evans, Ira N.
Fabricius, P. H.
Fentzlaff, A.
Fitts, J. L.
Fuller, C. A.
Goldwater, S.
Gulick, L. H.
Haensel, C. W.
Hanbury, J. F.
Harding, J. A.
Heath, F. R.
Hering, Rudolph
Hoffner, James
Hole, H.
Hutton, William
Ihshley, A. O.
Issertell, H. G.
Kehm, August
Kiewitz, A. A.
Kline, W. J.
Knuss, Edward
Lanning, E. K.
LeCompte, W. G.
Lewis, L. L.
Lloyd, E. M.
Lloyd, John M.
Lyon, D. T.
McCormick, W. G.
McCurdy, J. H.
McDermott, Chas.
McDuff, G. G.
McGonagle, Arthur
McKeag, George A.
Meier, Konrad
Mohr, Thos. F.
Morford, T. P.
Morgan, W. W., Jr.
Morrison, T. A.
Mott, Geo. T.
Munroe, W. R.
Murphy, E. T.
Newkumet, P. J.
Newman, Harold
Norton, F. M.
O'Crowley, R. J., Jr.
Orr, F. B.
Otis, James S.
Owens, H. T.
Phegley, F. G.
Phillips, F. T.
Quackenboss, L. H.
Raffin, E.
Regnvall, Gustav
Richardson, F. J.
Rowntree, Bernard
Samson, P. B.
Schroder, N. S.
Schwerer, R. C.
Scollay, John A.
Scott, E. A.
Seymour, C. H.
Slocum, C. A.
Smith, E. D.
Smith, H. M.
Sovereign, R. J.
Spragge, E. E.
Stennis, C. H.
Stevens, T. H.
Sweeney, J. H.
Taggart, R. C.
Terrell, H. A.
Thode, J. H., Jr.
Thompson, W. Gilman
Titzel, C. E.
Tolman, W. H.
Travis, Geo. F.
Von Gogh, E. P.
Wanner, Louis, Jr.
Wattles, J. W.
Ward, G. W.
Webster, E. K.
Wede, C. V.
Weld, A. O.
Wood, E. S.

LADIES.

Addams, Mrs. Homer	Collins, Mrs. H. E.	Macon, Mrs. W. W.
Andruss, Mrs. N. P.	Davis, Mrs. J. H.	Olvany, Mrs. W. J.
Armagnac, Mrs. A. S.	Donnelly, Mrs. J. A.	Shanklin, Mrs. J. R.
Barwick, Mrs. Thos.	England, Mrs. G. B.	Thomas, Mrs. M. F.
Bjerrejaard, Miss M.	Hinkle, Mrs. E. C.	Von Rehm, Mrs. M.
Bolton, Mrs. R. P.	Hummell, Miss L.	Williga, Mrs. F. L.
Bradbury, Mrs. C. R.	Inness, Miss H. R.	Wise, Mrs. S. S.
Busey, Mrs. F. L.	Mackay, Mrs. W. M.	
Chapman, Mrs. F. T.	Mackay, Miss J.	

PAPERS

OF THE

EIGHTEENTH ANNUAL MEETING,

New York, January 23, 24, 25, 1912.

CCLXXI.

THE USE AND THE ABUSE OF FUEL.

BY REGINALD PELHAM BOLTON.

PRESIDENT'S ADDRESS.

The subject of fuel is of fundamental importance to the heating engineer, and the economic utilization of available materials constitutes a most important part of the service of our profession, not only to our own clients, but to the community.

The use of fuel in the northern portions of our country is of vital importance, not merely to our industries, but to human existence during the occurrence of low temperatures, and any increase in its cost, or any shrinkage in its supply directly affects the comfort, and even the conditions of existence of a large proportion of the population.

A general advance has taken place during the year 1911 in the price of anthracite coal, upon the use of which fuel the metropolis is largely dependent, an advance probably to be followed by another increase during the current year. The lowest grade of anthracite has been advanced 10 cents per ton at the mine, constituting to the dealer a rise in cost of 15 per cent. with equivalent increase to the consumer. These advances are indications of the gradual approach of the period of exhaustion of the supply of this desirable and advantageous form of combustible material, and point to the not distant time when the city of New York will be confronted with the dreaded infliction of a general dependence upon bituminous or "soft" coal.

The evils anticipated from this material are of such long standing in other communities as to warrant the disinclination to its use in this city. Its consumption in London had become a public nuisance as long ago as the fifteenth century, and its contribution, by reason of the ineffective methods employed in its combustion,

to the unfortunate reputation of the British Metropolis for smoke-laden atmosphere, and its aggravation by the infliction of smoke-laden fog, has been universally appreciated, and feared.

As we must anticipate that in due course, hastened by present methods of extravagance in the use of anthracite, the use of soft coal may become the main source of heat supply in this city, it is a matter of general interest, to examine into any large cause, contributory to the unnecessary hastening of the situation.

The advance of modern improvements will no doubt gradually bring about better conditions in the combustion of soft coal so far as to reduce the nuisance of visible smoke, but it remains a fact that present extravagance in the use of fuel in this part of the country is not only helping to bring about the elimination of anthracite as a fuel, but, as in other parts, contributing unnecessarily to the eventual exhaustion of the accessible coal measures of all kinds in the East, a result which may eventually bring about the transfer to the West of our future industries, and perhaps of the larger part of the population of the country. These considerations indicate the desirability of serious reflection upon the need for the study of economic methods, and for the dissemination of information bearing upon the evils, present and future, of modern extravagance and recklessness in the use of the invaluable commodity with which nature has, to a not unlimited extent, provided us. Many of those to whom this subject is presented are apt to discount the urgency of the situation and its possible disadvantages to our successors, by reference to the availability of other materials for the production of heat. That other materials capable of utilization as fuels exist, and to a considerable extent, is true. Yet their use is not unaccompanied by waste of another kind, since their value for other purposes is greater than for that of mere combustion, and it is only when they take the form of a true waste product, incapable by reason of local or fixed conditions of more economic utilization, that they can be considered as proper substitutes for coal.

It is due to our effective, if perhaps indefinite appreciation of this fact, that coal is so widely applied to the exclusion of other apparently accessible sources of heat. The process is carried too far in some cases, as in that of the neglect to utilize the waste materials of cities.

Coal is, itself, a more or less misplaced material. Its existence

does not entirely coincide with the desirable location of great industries and with the developed situation of the greater centres of population. Its cost to such communities as that of New York is therefore largely made up of artificial additions due to its removal and distribution to the place of utilization.

The fuel, for which we pay from $2.50 to $6.50 per ton, has cost at the place of production barely a third of the amount. But such circumstances of location and carriage, in view of the vast developments and economies in modern methods of transportation, cannot be debited with the whole responsibility for the fact that coal has within the past half century increased in cost. A bill for coals delivered at retail on Broadway in 1853, which I found among other papers concealed in an old building recently destroyed, shows that the prices of fuel to the consumer was in those days less than is the case in the year 1912.

It has been due to some better application of known principles of draft and of furnace construction and proportion, that the smaller and cheaper grades of anthracite became utilizable, whereby advantageous use has been made in recent years of the rejected waste of earlier mining methods. The culm banks have, however, been diligently exploited and the product is no longer a waste material. The combustion of other cheap material may soon be forced upon our industries and power developments, by the shortage of the finer grades of fuel, which will be in necessarily higher demand as scarcity develops. Every indication thus points toward the desirability of advance consideration of the subject so vitally affecting our general welfare.

The alternative sources of present and future fuel for this part of the country probably lie in vast peat and lignite deposits of the East and South. But the use of some lower grades of fuel will require reconsideration of existing practices, re-arrangement of appliances and reconstruction of much of the fixed apparatus now in use.

Further development of the gas engine will contribute more directly to the effective utilization of such materials since it has been demonstrated that lignite, the heat value of which is not more than 75 per cent. that of coal, may be made to afford equivalent power by means of the gas producer.

These and other materials may be utilized ere long in substitution for the cheaper grades of coal, but such use will be accom-

panied by large costs of necessary appliances and some increasing complexities of operation.

The observant heating engineer, traveling over this country, is naturally impressed by the opportunities for the utilization of local materials for combustion, and sometimes observes incongruous conditions accompanying the apparently unnecessary use of coal. In the wooded districts, vast quantities of unused lumber rot on the ground, and along rivers and on the sea coast driftwood and wreckage litter the shores. Such materials are little utilized, though driftwood is sold in New York City at $6 a barrel, and small oaks and hickory cut to length brings $16 to $19 a cord.

In portions of the country where peat could be had for the cutting, coal is brought to be burned, and I recently saw the waste of a wood-working factory being dumped into a fill, in a mill using bituminous coal at $3.50 per ton.

Natural gas can be obtained at so low a price as 30 cents per 1,000 cu. ft. even as far away from its source of supply as Buffalo, yet soft coal is being consumed and ineffectively, with much accompaniment of smoke in that vicinity.

The wastage of one industry or process may be capable of supplying the fuel of a lesser, if properly applied, but it is not to be forgotten that waste materials are possibly capable of utilization in better form than combustion.

In the Northwest, millions of tons of straw and cornstalks are burned locally, and in the South vast quantities of cotton shells and fibre, capable of use either in the production of food materials or paper.

Neglect of one large opportunity is taking place in this and in many other cities, due to their failure to utilize the waste materials of the community, which are disposed of by common expense instead of being made the means of effective heat production. Under proper furnace arrangements, the rejected ashes, which contain a considerable percentage of unburned carbon, combined with the waste wood and paper, can be utilized effectively with the garbage of a city, to contribute more than the cost of the collection, in providing power for other purposes. The waste materials of a city the size of Havana would, under proper conditions, afford power for all municipal water pumping and sewage disposal.

The waste materials of the Borough of Manhattan, with a population of approximately 2,300,000 persons, is annually:

Of light, inflammable refuse	2,100,000 cu. yd.
Of ashes	3,000,000 " "
Of garbage	220,000 " "

The ashes contain approximately 20 per cent. of unconsumed carbon, representing a heating value equivalent to	168,000 tons of coal
The annual value of which is	$504,000
To which may be added the cost of disposition at 45c. per yard	270,000
Making a total of	$774,000 per annum

This large proportion of wasted fuel is due to the negligent methods of operation of domestic fires, to inefficient settings and proportions of boilers and furnaces, and to ineffective drafts for complete combustion.

With all the accumulated information of past experience and with all the improvements of the present day, the economics of combustion of fuel are not widely understood, and are little practiced. We find throughout this city to-day, comparatively few steam-generating boilers properly set, and many unprovided with proper draft for the fuel which is used. With a multitude of inventions and devices for so-called smoke-prevention, the simple principles of furnace construction, of proportion of grate to rate of combustion, of proportion of air supply and the advantages of high furnace temperatures, are neither understood by or taught to the man who handles the destruction of this valuable material, from the use of which are derived most of our comforts, our industries and our transportation.

A special obligation lies upon our Society, as representing engineers engaged in the art of heating, to impress upon the public, and, in particular, upon the users of fuel, a better understanding of these fundamental facts and principles. An immense amount of printed matter has been devoted to the description of appliances connected with the distribution of heat, but much less has

been done to educate the consumer in the economic utilization of the heat in the fuel for which he pays.

The waste and carelessness exhibited in this direction and the ignorance of the class of men employed in the combustion of fuel are factors which have hastened the development of central heat, light and power services.

It is inevitable that as time proceeds and the supply of conveniently available fuel becomes scarcer, accelerated by the volume of demand, increased by reckless wastages, the community will depend almost exclusively upon centralized and economically operated centres of heat, of light and of power production. It is natural that the course of economic developments should take this direction.

The economies in which it is difficult at present to interest the consumer of fuel become of commanding importance to a great industrial center of heat and power production. We have only to compare an average small steam engine and boiler in the isolated plant, using up coal at a rate of 10 lb. for the production of a kilowatt-hour, with the latest addition to the electrical generating plant in the Waterside station of the New York Edison Company, giving the same unit of force, for a destruction of less than 15 per cent. of that amount of fuel.

But while this process is in course of development, it is none the less necessary to impress upon the public mind the fact that the main source of artificial heat lies in the coal supply of our own country and that this is not an unlimited amount. Beyond its exhaustion lies the use of materials of limited value and also of limited amount, or a dependence upon developments of mechanical or chemical methods, involving expense and uncertainty such as we should reject, and perhaps resent, if offered or required as a substitute for the simple service of coal. Let us remember that for every ton of coal taken out, about an equal amount is necessarily abandoned in the mine; and that a large amount of available lumber is also destroyed or abandoned in the same process of extraction. Every year's working of the coal measures increases the difficulties of coal winning, and adds to its cost.

The best available information at this date limits the accessible supplies of coal, at our present progressive rate of consumption, to one hundred years. and the precedent conditions thereby

brought about may be experienced by the children of some of us here present. The time must inevitably come when legislation will restrict the right of the individual to waste fuel, in any direct and eventually even in any indirect manner, and we may well imagine that the work of the heating engineer will at that time become of prime importance to the welfare of the nation.

There is a final element in the production of coal which should make a special appeal for recognition of the evils of its unnecessary waste. The cost of coal is not paid in money alone, but in an inevitable price of human life and of injury to our fellow creatures. The terrible percentage of the loss of life to the tonnage raised, which obtained in the past, has been ameliorated only in the mere proportion which the number bears to the increasing tonnage raised, and not in the aggregate. It remains a fact that about two thousand lives are sacrificed each year in the production of the five hundred and fifty millions of tons of coal which we partly use and which we partly waste; and that five thousand persons, most of them hard-working men having others dependent upon their labor, are maimed and injured.

In the homes of this city alone, in which upward of six millions of tons of coal are annually burned for the comfort of their occupants, the effect of three millions of tons of which is largely thrown away, the waste represents a loss of ten human lives, while the annual coal consumption of Greater New York has involved as its share of the annual loss of life 68 persons killed and 170 sorely hurt or crippled. For no other material in common use do we pay so dearly in human life and limb, yet in the use of no other material is so little care exercised, so little relative economy practised, so little educative method followed.

Coal is really a common possession, a heritage of the past to our present times, a priceless gift of ages of slow accumulation, which is disappearing not only by mere necessary usage, but also in great part by reckless and ignorant misuse. It should be thought a high crime against the community to contribute to the injury and deprivation of our children whose welfare is bound up in the provision which nature has made for our own and for their benefit.

Surely, considerations such as these should specially impress every heating engineer and point to the duty that lies upon us, of

aiding in every way the elimination of preventable and useless waste and the utilization of every opportunity for economy in the material which constitutes the main support of our industries, one of the main sources of the country's wealth and the best means of maintaining the habitable character of much of the most desirable part of this country.

CCLXXII.

HEAT EXCHANGE DIAGRAM.

ITS APPLICATIONS TO THE THEORY OF AIR WASHERS.

BY N. W. AKIMOFF.*

The object of this paper is the presentation of the heat-exchange diagram given by F. I. Weiss in his book *Kondensation* some fifteen years ago. This diagram, although originally given in connection with the subject of cooling towers, can be admirably applied to the solution of various problems of treating air, so far as the cooling and the humidity control are concerned.

By way of introduction let us consider a pan, Fig. 1, filled with water at 120 deg. F. and exposed to air,—stationary or slowly moving,—of 60 deg. F. and (for the present) absolutely dry. From the steam tables we find that the steam pressure corresponding to vapor at 120 deg. F. is $p_s = 1.6828$ lb. per square inch, so that, according to Dalton's law, the pressure of the air proper will be the atmospheric pressure less the pressure of the steam, in other words, $p_a = 14.7 - p_s$.

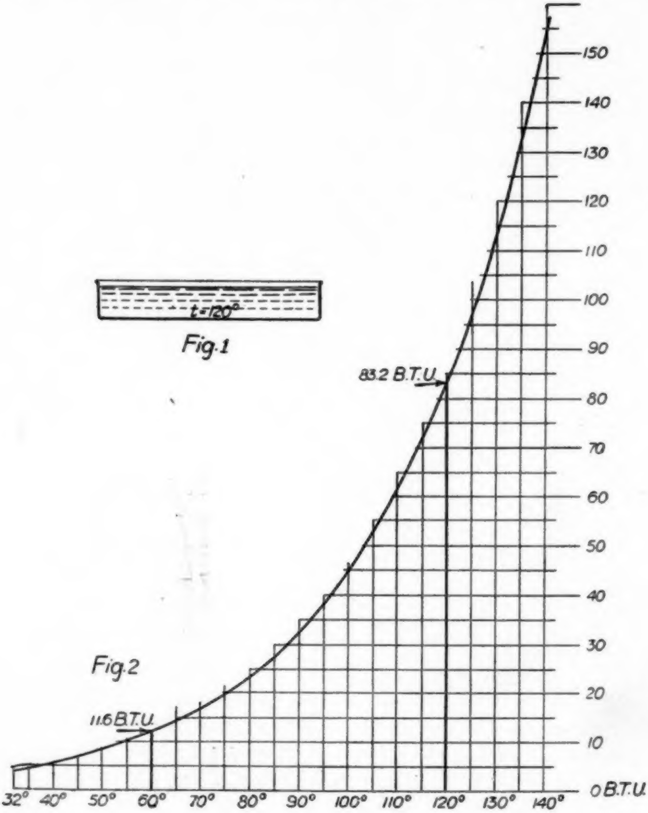
Knowing further, that, in the immediate vicinity of water, the air is evidently saturated with and of the same temperature as the vapor, we have to conclude that every cubic foot of air blown over the surface of hot water carries off one cubic foot of saturated steam at the temperature of the water. Being given therefore the total amount of heat given up by the water, we can calculate the proportion in which that amount of heat was divided between the air proper (due to the increase of its temperature from 60 deg. to 120 deg.) and the steam (due to evaporation).

Our present problem is then, *knowing the total amount of heat H carried away with the air, to find h_a, heat due to the heating of the air, and h_s, that due to the evaporation, remembering that $H = h_s + h_a$.*

* Non-member; Engineer, Philadelphia.

HEAT REQUIRED FOR VAPORIZATION.

Knowing that 1 cu. ft. of (absolutely dry) air carries off 1 cu. ft. of vapor, we can easily find the amount of vapor, carried away with 1 lb. of air, when in contact with and of the



same temperature as the water, so that the actual pressure of the air is as before $p_a = 14.7 - p_s$.

The characteristic equation for the air being $PV = RT$, or, simply $144\ p\ V = 53.34\ (t + 460.7)$,—where the pressure has been reduced to pounds per square foot, the constant R being taken as 53.34, and the absolute temperature has been ex-

pressed in terms of Fahrenheit scale,—we at once have the volume of 1 lb. of air (in immediate contact with the water, and therefore the same as the volume of steam included therein)

$$V = \frac{RT}{P}, \text{ or, with our notation, } V = \frac{53.34\,(t + 460.7)}{144\,p_a}$$

Knowing the temperature, and therefore the specific weight of the vapor, γ, we have the weight of vapor, contained in 1 lb. of air

$$= \gamma\, V = \gamma\, \frac{53.34\,(t + 460.7)}{144\,p_a}$$

The latent heat or the heat of vaporization at t deg. being $r = 1091.7 - .7\,(t - 32)$, the amount of heat of vaporization corresponding to 1 lb. of air, blown over water, will be

$$h_s = r\,\gamma\, V = [1091.7 - .7\,(t - 32)]\,\gamma\, \frac{53.34\,(t + 460.7)}{144\,p_a}$$

Various values of h_s given as ordinates corresponding to temperatures, taken as abscissæ, have been plotted on diagram, Fig. 2, while the accompanying table gives the numerical results of calculations of separate items constituting the above expression for h_s.

TABLE FOR "HEAT EXCHANGE DIAGRAM"

(1) t Fahr.	(2) $R.T.$ ft.-lb.	(3) p_s lb. per sq. in.	(4) $144p_s$ lb. per cu. ft.	(5) $\frac{R.T.}{144p_s}$ cu. ft.	(6) γ lb. per cu. ft.	(7) (5) × (6) lb. steam per lb. of air	(8) r heat of vaporization	(9) h_s (8) x (7) B.t.u.
32	26280	0.0890	2104	12.49	0.000295	0.003687	1091.7	4.025
40	26707	.1216	2100	12.714	.000399	.005073	1086.	5.509
50	27240	.1773	2091	13.027	.000573	.007466	1079.1	8.056
60	27774	.2545	2080	13.35	.00081	.01081	1072.1	11.589
70	28307	.3602	2065	13.708	.00113	.01549	1065.2	16.6
80	28840	.5027	2044	14.109	.00155	.02187	1058.2	23.143
90	29374	.6925	2017	14.56	.00210	.03058	1051.4	32.152
100	29908	.9421	1981	15.1	.00282	.04258	1044.4	44.471
110	30441	1.2663	1934	15.74	.00374	.05887	1037.5	61.078
120	30974	1.6828	1875	16.52	.00489	.08078	1030.4	83.236
130	31508	2.2119	1797	17.53	.006336	.11107	1023.5	113.68
140	32041	2.8774	1702	18.82	.00812	.15282	1016.4	155.33

It will be seen from Fig. 2 that, for instance, 1 lb. of air (dry) when blown over water at 120 deg. will carry off 83.2 B.t.u. *regardless of its original temperature.* If, however, the air orig-

inally was not dry, but contained, say, 0.01 lb. of water (or vapor) per pound of air, then the amount of vapor given up by the water, as well as the corresponding amount of the heat of vaporization, will be decreased by 0.01 lb. and by 0.01 r, respectively.

If the air was originally saturated with vapor, the heat of vaporization will be decreased by the full amount corresponding to the original temperature of the air. If, for instance, we suppose that the air was originally saturated at 60 deg., the heat of vaporization corresponding to this temperature is (see Fig. 2) = 11.6 B.t.u. In order, therefore, that the diagram, Fig. 2, may answer for the saturated steam at 60 deg., we should lower the curve by that amount 11.6 B.t.u. The same result may be obtained by shifting the axis of temperatures up by that amount, which has been done in Fig. 3. We thus see that 1 lb. of saturated air at 60 deg. can absorb only 71.6 B.t.u. (since 83.2 — 11.6 = 71.6), as shown by *ab*, from the water at 120 deg.

If, however, the air originally was not saturated, but contained a certain amount of humidity, say, 75 per cent., then the axis of temperatures should be moved up not by 11.6, but by 0.75 × 11.6 = 8.7 B.t.u., in which case 1 lb. of such air is capable of absorbing 83.2 — 8.7 = 74.5 B.t.u., as shown by *cd*.

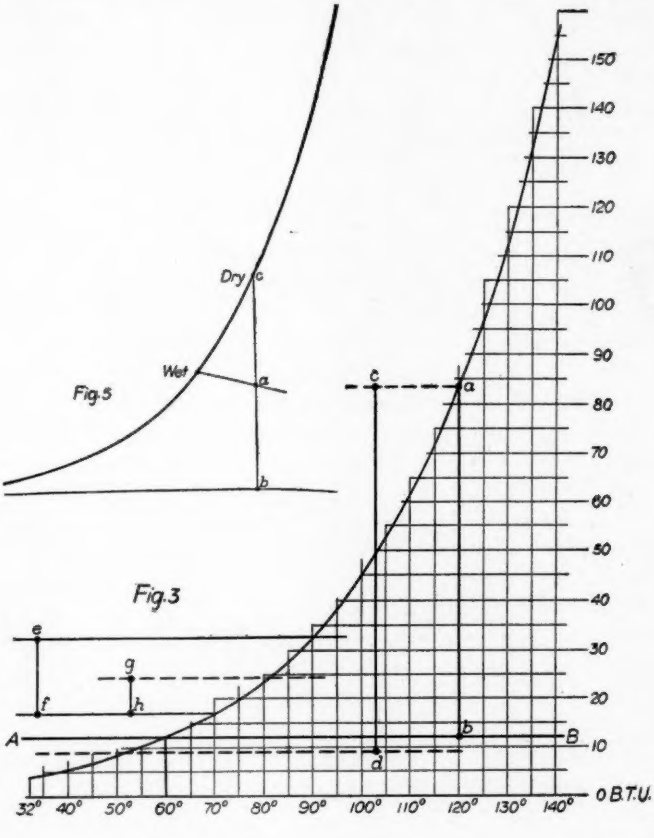
Referring again to Fig. 3, we may observe that if the values *above* the new axis *A-B* are to be considered *positive*, those *below* *A-B* will necessarily be reckoned *negative* and will mean heat given up to the water by the 1 lb. of air, so that the result will be *cooling* of the air and *heating* of water. For instance, 1 lb. of saturated air at 90 deg. will yield 32.2 — 16.6 = 15.6 B.t.u. to water at 70 deg. (as shown by *ef*) and under the same conditions air of 75 per cent. humidity will yield 0.75 × 32.2 — 16 = 7.5 B.t.u. (see *gh*) to water at 70 deg. This is the well-known phenomenon of de-humidifying.

HEATING OF THE AIR PROPER.

Assuming as above, that the air of t degrees while in contact with water at t_1 deg. is heated to the latter temperature, we have the heat exchange expressed by the following formula:

$$h_a = C_p (t_1 - t) = 0.24\ (t_1 - t)$$

where h_a is the number of B.t.u. acquired by 1 lb. of air and $C_p = 0.24$ is the specific heat at constant pressure (which rough value is satisfactory for ordinary industrial applications). This is the equation of a family of parallel straight lines,



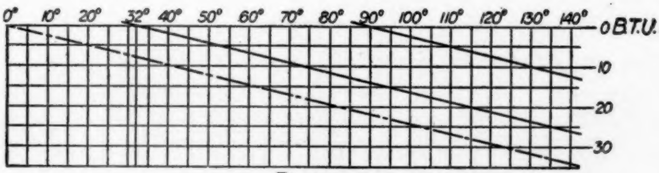


Fig.4

whose tangent with the axis of temperatures is = 0.24, provided of course that the scales of heat and temperature are alike, otherwise a suitable correction will have to be introduced. Fig. 4 represents a chart on which various values of h_a have been laid out. All these lines will in future be referred to as h_a lines. It will be seen that 1 lb. of air of 0, 32 and 90 deg. will absorb from water of 120 deg. the following amounts of heat, 28.8, 21.1 and 7.2 B.t.u., respectively. The above formula is correct for dry air, but in using it for air containing a reasonable degree of moisture the error will not exceed a few per cent.

HEAT EXCHANGE CHART.

Figs. 2 and 4 may be combined into one and the resulting diagram, Fig. 6, gives a ready solution for most problems connected with the subject of humidity and cooling. The use of this diagram will be best understood from the following practical examples:

1.—Find the amount of heat that may be absorbed by 1 lb. of air at 80 deg. and of 60 per cent. humidity. Locating a point corresponding to 60 per cent. of the ordinate drawn through 80 deg. (Fig. 6), we draw the following two lines through this point: a line parallel to the axis of abscissæ, whereby we take into consideration the initial humidity of the air, and a line parallel to h_a, to account for the heating of the air. If now the hot water is at 120 deg., we can at once tell that the total amount of heat absorbed by 1 lb. of air is 79.5 B.t.u., of which 9.5 was expended on heating the air itself and the balance, 70 B.t.u. corresponds to evaporation, giving, as a result, saturated air of 120 deg.

In other words, the water has lost 79.5 heat units and, unless there is a constant supply of heat, the water will be cooled down to 80 deg., which is the temperature of the air. After this point has been reached, the water will not be able further to heat the air, but it will lose more heat on account of evaporation (the air of 60 per cent. humidity having 40 per cent. additional capacity).

At 75 deg., for instance, the following heat exchange will take place: the water being cooler than the air, the latter will lose about 1 B.t.u.; on the other hand, the water will yield to the air

about 5.5 B.t.u. on account of evaporation; the result will be 4.5 B.t.u. given up by water, which will further cool it. As soon, however, as the point is reached corresponding to 69 deg. (intersection of the h_a line with the curve), the heat exchange

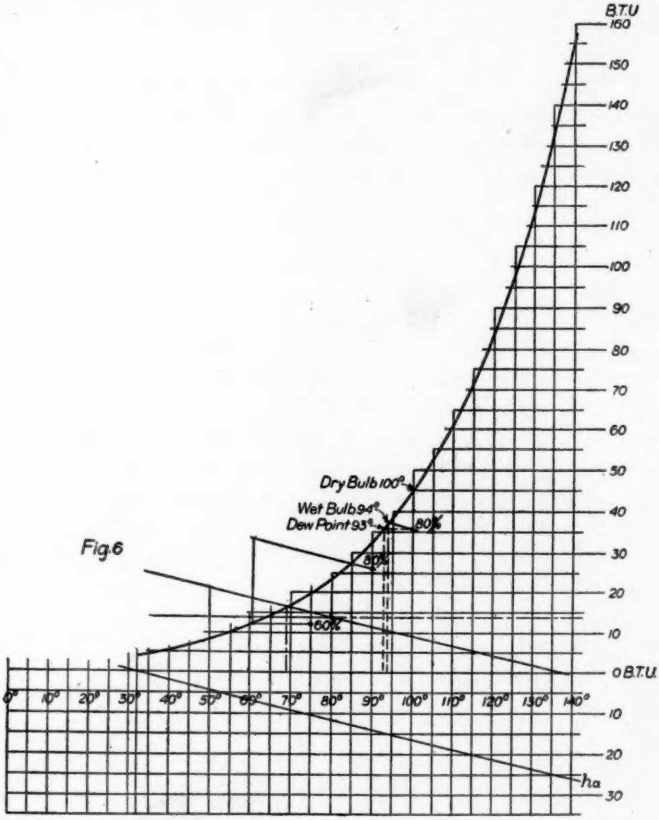


Fig. 6

stops, as the air gives up 2.5 units to the water, which in turn gives up the like amount to the air, so that the temperature of the water remains constant, regardless of the amount of air (of 80 deg. and 60 per cent.) that may be blown over its surface. This is the *wet bulb temperature,* and a ready method is thus afforded for determining the relative humidity of the air (Fig. 5). Through the point, corresponding to the wet bulb tempera-

ture draw a line parallel to the h_a line (on Fig. 6) and mark its intersection *a* with the ordinate corresponding to the dry bulb temperature. The ratio *ab*:*bc* will then be the exact value of relative humidity.

2.—Given dry and wet bulb temperatures (100 deg. and 94 deg.) as above, find the dew point. Through the point corresponding to the humidity of 80 per cent. found as above draw a line parallel to the axis of temperatures. The temperature thus found, 93 deg., corresponds to the state of conditions where the heat that could evaporate only 80 per cent. of the maximum amount corresponding to 100 deg., is just sufficient completely to saturate the air at that latter temperature (93 deg.) which is the very definition of the dew point method. In other words, out of the four quantities, the dry-bulb temperature, the wet-bulb temperature, the relative humidity and the dew point, any two can instantly be found if the other two are given.

3.—Let us suppose that the water in the example 1 has been artificially cooled down to 50 deg. The air (80 deg. and 60 per cent.) will now give up about 7 B.t.u. due to the decrease of its own temperature to 50 deg.; on the other hand it will yield to the water an additional amount of about 5.5 units, due to the condensation of a certain amount of its own vapor, the total amount of heat *received by water* being 12.5 B.t.u. per pound of air. This will increase the temperature of water until it reaches 69 deg. as above, which corresponds to some sort of a stable equilibrium for given conditions. It is important to note that to the right from this neutral point (wet-bulb) the water is being cooled and the air heated. To the left, the reverse takes place.

4.—How can air of 90 deg. and 80 per cent. humidity be reduced to 75 deg. and 60 per cent. humidity? Referring to Fig. 6 this can easily be done. Through the point corresponding to 75 deg. and 60 per cent. we draw a line parallel to the temperature axis and thus find the corresponding dew point, about 60.5 deg. The air *must* be cooled to this temperature and then heated again to 75 deg. In order to find how many B.t.u. will be thus extracted out of every pound of air, we draw a vertical line through the dew point temperature and find its intersection with the h_a line, drawn through the point corresponding to given conditions (90 deg. and 80 per cent.). The

result will be about 21.5 heat units to be extracted per pound of air. From this we can find the capacity of the ice machine in tons per 1,000 cu. ft. of air, by multiplying by Mr. Macon's coefficient 0.35,* so that $21.5 \times 0.35 = 7.5$ tons refrigeration per 1,000 cu. ft. of air.

GENERAL REMARKS.

The constructions shown above should not be followed mechanically or memorized, but the meaning of each line constituting the diagram should be clearly understood. The *curve* represents 100 per cent. saturation, and gives the total number of heat units required for same. It likewise gives temperatures corresponding to the dry and wet bulbs and to the dew point. The ***horizontal lines,*** drawn through various points representing certain percentage of humidity, show the decrease of evaporation due to the humidity already present in the air; they also may be considered as lines of ***equal absolute humidity,*** while the corresponding relative humidity varies from 100 per cent. (dew point) to a lower percentage, according to the temperature. The h_a lines show the amount of heat required (or given up) by the air itself. Their intersection with the curve is the wet-bulb temperature and the short side of the triangle formed by an h_a line, a horizontal line and any vertical gives the amount of heat absorbed or given up (according to the position to the right or to the left from the intersection) by the air proper.

USUAL MISTAKES MADE IN DISCUSSING THE SUBJECT OF COOLING OR HUMIDITY CONTROL.

1.—The meaning of the wet-bulb temperature is mostly misunderstood. The following is quoted from an otherwise excellent book on heat. . . . "Since the wet-bulb thermometer receives heat by radiation from surrounding objects and the pressure of the water vapor in its neighborhood, due to constant evaporation, is higher than elsewhere, it will not indicate a temperature as low as the dew point. It is necessary, therefore, to make use of the following empirical table, etc., etc." . . . This is not a very clear explanation and we have seen that it is

* Transactions, Vol. XV, 1909, p. 130.

not at all necessary to depend upon the empirical formulæ, since the steam tables can furnish an exact answer. Furthermore, the wet-bulb temperature is not at all meant to be anything like the dew-point temperature. We have seen its true meaning. And again, in finding the dew point by direct methods, we do not seem to care very much for the heat received from the surrounding objects. The above is very confusing, and the diagrams may help to make things clearer.

2.—According to some of the experts, the *reliable data and information can only be obtained from actual tests.* In a well-designed washer the simple calculations set forth above will be found to represent the true nature of things within possibly a few per cent. The suitable factors of correction that may be introduced will not decrease the usefulness of the diagrams any more than that, say, of the graphical method of figuring a quadruple-expansion steam engine. And all the above is not meant for a poorly designed washer. A storm of 60 miles will scarcely be expected to absorb much moisture per pound of air from water at 120 deg. (Fig. 1).

3.—There seems to be a superstitious belief among some of the washer folks that in order to increase the humidity of the air at constant temperature it is sufficient to raise the temperature of water above the dew point. It will be seen from the diagrams that this may not be quite enough. The temperature of the water must be raised above that of the wet-bulb; *how much* above will depend upon the degree of humidity desired. Intersect the curve by an h_a line, drawn through a suitably located point, corresponding to the desired humidity, and raise your water temperature above *that.*

4.—It is likewise wrong to say that in de-humidifying it is enough to drop the temperature of water below the dew point of entering air. The question is how much below, and the ready answer will be found from our diagrams: drop the temperature of water to (or slightly below) that, corresponding to the dew point of the new conditions.

5.—It is sometimes stated that the cooling of the *air takes place largely through evaporation.* According to this it would not be possible to cool air of 100 per cent. humidity, which, of course, is absolutely wrong, and it may be seen from the diagrams that the exchange of heat does not solely depend upon

evaporation, and that therefore it is possible to cool saturated air through its contact with cold water (or a cold brine pipe) as well as through condensation of a certain portion of vapor contained in the air. *Evaporation cools the water, not the air.*

All such errors simply prove that the subject is not quite clear even to some of those who claim to be masters in the profession. It is the sincere hope of the writer that this paper will help to make things easy not only to the mind of the designer, but also to that of the consulting engineer or the architect, who may thus clearly see what can be done and how it should be done.

CCLXXIII.

DRYING APPARATUS.

BY H. C. RUSSELL.

The subject of drying as a process in the manufacture of many articles of everyday use has not received its share of attention at the hands of this Society or of any other scientific body; and related as it is to the work of the heating engineer, for, indeed, it often forms an integral part of the heating apparatus itself. It is the hope of the author that this paper will create an interest in this subject, and will result in profitable data being presented to the Society.

It is not the purpose of this paper to discuss the drying of any particular kind of material, but rather to call attention to some of the principles underlying the design of drying apparatus in general. Drying is usually a process in manufacture and in such cases the dryer is generally located in the factory with a view of entailing as small an amount of extra handling of material as possible.

The manner of constructing the drying tunnels or compartments, the amount of air to be circulated, the temperature of this air, and indeed almost every detail of design depends upon the material to be dried and its amount. For different classes of material these details will vary over a wide range. Some materials are very sensitive as regards air conditions in the dryer and others will stand considerable abuse.

It is one of the underlying principles of many kinds of dryers, and applies with peculiar force to the drying of lumber and such materials, that the hot air to the drying tunnel must be admitted close to the "hot" or "dry" end of the tunnel, and discharged at the "wet" or "green" end. It will be observed that there will be a wide difference in relative humidity of the air between the hot end and the opposite end, usually called the "green" and, because of the moisture the air has absorbed (it being the sole function of the dryer to absorb moisture). There

will likewise be considerable difference in temperature between the two ends because the heat required to evaporate the moisture, supply radiation losses, etc., is usually taken from the air supplied by the fan.

If now the green material, especially such materials as lumber, should be first placed in the hot end of the dryer where the air is hot and very low in its relative humidity the rapid evaporation and consequent drying of the surface would cause surface cracks or checking, since practically all materials contract more or less in drying. On the other hand, if the green material is placed first in the green or wet end of the dryer where the temperature is lower than at the other end, and what is more important, the relative humidity is much higher, the drying at first will be very slow, giving the material a chance to get at uniform temperature throughout and the drying process will begin at the centre even before it begins at the surface because the very moist air will prevent nearly all evaporation from the surface until it is moved farther along the dryer into regions of lower relative humidity. This is the method used in a large percentage of dryers.

As each particular class of dryers has certain peculiar features which make it different from all others, it is beyond the scope of this paper to deal with them, except perhaps to say that the material may make its trip through the dryers loaded on trucks, in trays stacked on cars, on conveyors or in perhaps half a dozen other ways as best suited to the particular proposition in hand. Dryers of this class are arranged to receive the fresh material at the so-called green end, the material being gradually advanced toward the hot end as the dried product is removed from the dry end and fresh material put in at the green end.

There are other classes of dryers where the air conditions may just as well be kept about the same at all times and in all parts of the dryer. In such cases the air may be distributed in a fairly uniform manner throughout the dryer. There are still other classes of dryers in which a full charge of green material is put in. The fan is then started and the temperature gradually raised and varied at will. In such dryers of course the air conditions will be practically the same in all parts of the dryer at any time.

The drying compartments or tunnels, as they are often called,

vary widely in design and are usually arranged with certain manufacturing conditions in view as well as the efficiency of the dryer. These manufacturing conditions need not and should not be allowed to impair the efficiency of the dryer. As a general rule, dryers for a particular class of work will be found to be about the same length, that is, if they fall under the first class of dryers named above, and the difference in capacity required will be made up as width or two or more dryers installed. For the last two classes of dryers the shape of the drying compartments is not so important, and they will be found to be made in a variety of shapes.

The size of the compartments will, of course, depend upon the amount of material, time required for drying and the space required for a unit quantity of material. The construction should naturally be fairly non-conducting, at least as much so as the best class of building construction, to avoid unnecessary waste of heat by radiation.

Temperatures.—It has been found that for practically each material the maximum temperature in the dryer for good results should not exceed a given figure and for temperatures much below this figure in the hottest part of the dryer the capacity will either be reduced or the material will not dry at all. Some of these temperatures are given in tabular form hereafter.

Drying Period.—For each material there is a minimum drying time which, of course, varies very widely for different materials. If we try to extract the moisture from any given material in much less than this time we will get unsatisfactory results due to too rapid evaporation. Some drying periods are given in tabular form hereafter.

Humidity.—It will generally be found when hot air is first brought into contact with the material which is almost dry (the air gradually absorbing moisture as it passes along toward the wet end of the dryer and the fresh material) that no trouble will result from too rapid evaporation unless the air supply is too great or the temperature too high.

Generally if one bases his calculations on about 60 per cent. relative humidity at 50 deg. outside temperature he will be safe, because when the outside temperature is below 50 deg. one can dry with a smaller volume of air, due to the fact that the moisture absorbing capacity of the air will be greater, and when the tem-

perature rises above 50 deg., the relative humidity will likely be lower than 60 per cent. or the temperature of the dryer may be increased somewhat. The relative humidity and temperature can, of course, be calculated from the above assumed conditions. At the green end the relative humidity, of course, differs greatly for different classes of work. Very seldom can it be made to exceed 75 per cent. at the temperature of the air leaving the dryer.

Moisture.—The amount of moisture to be evaporated in a unit of time must always be known for intelligent design. This can be found by simple experiment if in no other way.

Air Supply.—Between the temperature of incoming and outgoing air there must be sufficient heat given off to take care of the following heat losses: (*a*) Radiation from the dryer, (*b*) Heat required to raise the temperature of the products to be dried, the water to be evaporated and the trucks, etc., from factory temperature to dryer temperature, (*c*) Heat required to evaporate the moisture based upon the latent heat of evaporation at the temperature at the wet end of the dryer. The air may be safely admitted to the dryer at a temperature above that given in the table hereafter to offset all losses except the last named.

There are two requirements as to air volume which must be met: (*a*) There must be a sufficient volume of air as a vehicle for carrying sufficient heat to provide for all the above heat losses without reducing the temperature at the green end too low for good results, (*b*) There must also be a sufficient volume of air to carry away the moisture without coming too near the point of saturation. This latter is to be calculated on a basis of the difference in the amount of moisture contained in a cubic foot of air as delivered to the dryer and that contained in the same air as it leaves the dryer, the relative humidity at the green end never to exceed 75 per cent. We should remember that most tables giving the amount of moisture contained in air at various temperatures and for various percentages of relative humidity refer to a cubic foot of the mixture of air and vapor and that the number of cubic feet of air (comparatively dry) going into the dryer may or may not be even approximately the same as the number of cubic feet of the mixture of air and water leaving the dryer.

It is imperative to see that both the above conditions as to the

amount of air circulated to carry away moisture be fulfilled. I have noticed that most of us are rather inclined to overlook the second condition; and in a large percentage of the cases, this condition requires more air than the first. It is evident that the dryer is most economical which satisfies both these conditions and overdoes neither, and this is the condition sought for as near as practicable. For instance, we may discharge a large volume of air into a dryer resulting in a small temperature loss and a comparatively low relative humidity at the wet end, and it might easily happen that we can use a much smaller volume of air at the same initial temperature with a greater loss of temperature in the dryer and a greater relative humidity at the discharge end and get results just as good or even better and certainly be more economical in the use of steam.

Loss of Temperature.—After allowing for all heat losses except those required to evaporate the moisture, the further loss of temperature in the dryer, of course, bears a definite ratio to the amount of moisture we can induce each cubic foot of air to carry away, which, of course, reverts back to the relative humidity at the discharge end. In the ordinary waste heat brick dryer this loss is about 100 degrees; in lumber dryers, it varies from 30 to 70 deg., and for the majority of other classes of dryers it runs from 10 to 30 deg.

The accompanying table gives the maximum temperatures, and in some cases the average drying period, for a few materials which have come under the author's observation. Dryers for lumber and brick have by reason of their commercial importance been given considerable attention and very reliable data have been secured.

CONDITIONS FOR DRYING DIFFERENT MATERIALS

Material.	*Temperature, Deg.*	*Drying Period.*
Sole leather hides	90	4 to 6 days.
Thin leather hides	90	2 to 3 days.
Bone glue	70 to 90	4 days.
Skin glue	70 to 90	2 days.
Starch	180 to 200	12 hr.
Apples	140 to 180	6 hr.
Leaf tobacco	85	
Stem tobacco	200	
Soap	100	2 days.
Wool	105	
Rags	180	
Pottery	120	

In many drying installations waste heat can be utilized for the purpose. All brick and tile yards of modern design are now

drying their products from waste heat derived from kilns cooling down after being burned, and it so happens that if the rotation of kilns is properly studied and adhered to there is waste heat available practically at all times in about sufficient amount for drying the fresh product with a liberal allowance for waste. After all very little of this so-called waste heat is really wasted. Much more can be accomplished in the way of adapting dryers to use waste heat, and furthermore the air can generally be drawn directly over the cooling surfaces themselves, for we are seldom interested in the absolute purity of the air supply to such dryers.

All that has been said above refers to dryers equipped with fans for providing a definite amount of air.

Dryers, of course, have long been in use which work by gravity, and it cannot be said that they were all failures. Indeed, it seems that for some work, notably lumber, they give better results than blower kilns.

The writer has seen many so-called dryers designed by some rule of thumb which gave fairly good satisfaction, but just how they did it I could never make out. The idea of the designer seemed to be to get his dryer as nearly air tight as possible, and to keep it as hot as possible, but fortunately his methods of construction were so imperfect that the air "leaked in" and "leaked out."

It is true that necessity is the "mother of invention," and the reason drying apparatus is just now in the experimental stage is seen in the fact that we are now approaching a point in our industrial development when the best and the cheapest that science and art can produce will be demanded.

The writer hopes to be able from time to time to present more detailed data covering some of the more important classes of dryers which the limit of this paper and the time allowed for its preparation would not permit its being incorporated herein.

DISCUSSION.

Prof. William Kent: There are some kinds of drying apparatus that consist of a cylinder which is rotated at a certain low velocity and the material is fed in at one end, turned over and over and dumped out dry at the other end. The cylinder may

be heated at one end by fire or it may be heated by steam coils placed inside or it may be heated only by hot air or gas that passes through.

I wish the author would take up the question of, say, given a mass of material containing 1,000 lb. of water, a maximum temperature allowable, of, say 200 deg. F. for some materials, maybe 400 deg. for others, such as sand, and tell us how that may be dried or heated with the greatest economy. As far as I have been able to find, the greatest economy is when we use no air at all, provided the substance may be heated above 212 deg. But as a high temperature cannot be used with some substances it is necessary with these to use air, and calculation seems to show that the larger the amount of air, the less economical is the operation.

It would be an interesting problem to figure up, say, with 1,000 lb. of water in a given quantity of drying material, what would be the cost of fuel or the number of heat units required with different quantities of air, different temperatures at the point of introduction of air, also with different temperatures of steam in the coils.

I came across a case the other day where a man had a sand drier made of a rectangular brick stack probably 40 or 50 ft. high, with a number of cast-iron plates projecting like shelves from two opposite sides, the sand dropping from one shelf to another. There was a fire at the bottom; the sand was discharged near the bottom. That is the way Mr. Edison dries crushed rock at his cement works at Stewartville, N. J. After running the stack in this way the man took out the plates and put in a distributing machine at the top of the stack, so that the sand fell down like rain, and with no plates at all he got better results. That was one instance of successful use of the rule of thumb.

Mr. Wolfe: Do you think you can dry in a vacuum, no matter what the temperature is?

Prof. Kent: I suppose so, if you take long enough, and maintain the vacuum, drawing off the vapor with a pump. I have dried a piece of coal, taking 14 per cent. of moisture out of it, by putting it in a desiccator, a closed glass vessel containing sulphuric acid, and letting it remain there for six weeks.

Mr. Wolfe: According to Dr. Billings's tables for drying, he

contends that it is the air that dries and not the heat. His tables give the amounts of moisture that the air will carry at different temperatures. If I remember correctly, at 57 deg. F., the air will carry one-eightieth of its weight in water. With every 27 deg. rise in the temperature of the air, you double its water-carrying capacity until you get up practically to 212 deg. when the water vaporizes.

The reason that sand coming down like rain dries easily is that there is a better contact with the volume of air passing through. The great loss of heat in drying is due to the loss of contact.

Mr. Donnelly: A great deal of rubber is dried in vacuum apparatus, by producing a vacuum in the dryer, heating with steam and evaporating the water out of the rubber and passing it into a condenser.

Prof. Kent: That is the way sugar is produced from the juice of sugar cane, by evaporating the water in vessels in which a partial vacuum is maintained.

In the operation of drying milk I have seen two large metal cylinders that came within a few thousandths of an inch of each other. The milk was poured down in the space between the rotating cylinders and came out below the narrow space dry. It was then scraped off by a scraper. In this case the drying was done entirely by heat. There was a steam pressure in the cylinders of about 150 lb., or over 300 deg. F. temperature. The water was entirely evaporated, and the dried milk as scraped off was packed in boxes and shipped, in the case I speak of, to the Japanese army.

President Bolton: I happened to be observing the operation of a large lumber-drying plant recently. I found closets prepared for the drying of special lumber which were entirely closed up, with no air access to them at all and carrying a very high temperature.

Mr. S. A. Jellett: The subject of drying is a particularly broad one. I think it starts first with a study of the goods you are going to dry. I have had experience in drying a great many materials, including laundry soap and sand soap, oilcloth, brick, leather, playing cards and you cannot apply the rule you use for drying one material to any of the others.

For example, in the case of playing cards, they are generally

put through a press for the final glazing, giving a pressure of some tons to the square inch. The only surface from which you can extract the moisture is the edge, which is about 0.01 in. thick. If you extract moisture from the glazed surface, it will ruin the card. Therefore, you must screen the air, or you must be sure there is no dust to stick to the card and then you must extract the moisture from the edge. As a rule, playing cards are printed in sheets which are dried before they are cut. Therefore you have to take the entire moisture from the edge of that sheet and each sheet contains a whole deck of cards. It takes some days to accomplish it.

In the case of laundry soap, the thing to do is to put a skin on it so as not to take too much of the moisture out. If you should treat sand soap that way, the minute a cake of soap was put in a bucket of water, it would dissolve. Therefore sand soap must be dried through the cake.

If you are drying oilcloth, you must study the effect of heat on the colors. If too much heat is applied to a scarlet or vermilion it changes it to give a bronzed effect.

I do not believe you can dry nine-tenths of the materials manufactured successfully without a circulation of air with the heat. With certain materials it is necessary to keep the temperature down, such as glue. If glue is heated to a temperature of 96 or 98 deg. F., it will never dry, but will simply get soft. They do not make glue in the summer months for that reason. Glue has roughly 80 per cent. of moisture in it—and after you get through with it, it must be dry enough to pulverize into powder. The drying of glue is accomplished in about 56 hours or less, whereas it formerly took some weeks. You have to watch the conditions, also, very carefully. As glue sets, it will stand a higher temperature. But if the temperature becomes too high, a skin will form over the glue which will hold the moisture inside.

The same thing is true of bricks. If you use too high a temperature at the start in drying bricks, a skin will form and the brick will crack. Bringing the moisture to the surface through this skin is what makes the cracks.

Speaking generally of moisture in air, I remember one case where I was called in to investigate the conditions in a chemical works. The superintendent had been in the habit of drying in

a certain way, with a network of pipes under a slat floor. He told me he had five miles of pipes in that room, which was about 150 ft. square. The moisture was trickling down the walls in streams and the windows were screwed fast. I told him to open the windows and he would get more drying. In this particular case, he had temperature enough to release the moisture from the material, but it was necessary also to have sufficient volume of air to carry the moisture away.

We find all those theories combated by the so-called practical man. I was consulted by a soap powder company in New York a few years ago on the matter of the drying of sand soap. After studying the material, I suggested that instead of drying it, we freeze it. The people looked at me in amazement. I said, "Take that solid piece (it was 42 in. square and 28 in. high) across the street and have it frozen. Then grind it while it is frozen and do not let it stand until it has thawed." The owner tried the experiment and it was entirely successful. After being in the cold storage room, where the temperature was below the freezing point, the soap was put in the grinder. It cost less money to freeze it and then grind it than to heat it and grind it. When the owner built a new factory he put in a refrigerator to freeze his soap.

President Bolton: We have here some definite information on the drying of the lumber, which is one of the great industries to which heating processes are applied. Observing the operation of a lumber-drying plant recently, I found that the closets for the drying of the lumber were entirely closed up, without any provision for air renewal, and evidently depended upon the capacity of absorption of the confined air at a very high temperature. This subject affords opportunity for a divergence of opinion; and from my own point of view I would like to see the subject pursued further, as Professor Kent has suggested. I hope we will get more data from the author, and that some of the members will contribute in writing what they have not contributed in discussion during the consideration of this paper.

CCLXXIV.

DUST IN RELATION TO HEATING.

BY KONRAD MEIER.*

It is a popular notion that steam and hot water systems give a different sort of heat. Engineers would define this more correctly by stating that various methods of heating will produce different air conditions. The old-fashioned devices are still considered by many people to be more wholesome, even though less efficient than the modern apparatus, of which it is often said that it does not ventilate, the dead air and stuffiness being attributed generally to the lack of air supply incidental to heating. Partly out of this idea has grown the popularity of the indirect system, but now complaints are heard, that through heating, and even tempering, by stacks, the air will lose its natural sweetness and refreshing qualities. The recent tendency to oppose plenum ventilation on the part of the medical profession appears to be the result of such observations. Engineers themselves will have observed, especially in public buildings and schools, that even a generous plenum supply will not make the occupants forget the desire to open the windows. Heated but unoccupied rooms are often found stuffy, even after long vacancy, when natural ventilation, which is always present, should suffice to keep them sweet. Everybody has noticed the stifling air of ill-kept empty railroad coaches which is not altogether caused by overheating, nor by previous occupancy. In such cases the foulness of the air cannot be due to lack of ventilation alone. These circumstances would indicate a cause of vitiation aside from the well-known sources and explains in a measure the demand for purer air which has really arisen and become general only with the introduction of the modern ways of heating.

None of this evidence is proof that the heating apparatus itself is at fault, but it should certainly raise the question, whether the quality of room air is altered in any material way by the

* Non-member; Consulting Engineer, New York.

process of heating. Changes in temperature and relative humidity, even though they bear on comfort to an extent, would not account for it, since we know they do not in themselves affect the sweetness of the air at least within the wide range between a brisk, dry, cold, northwest, and the moist, warm, ocean breezes in summer.

If it be found, that the air is undergoing chemical, physical, biological or only purely thermal changes through any of the prevailing methods of heating, we will then have to answer the next question, whether such deterioration is of any consequence, in general, or only in particular cases. When the causes and effect are determined, we will be able to prescribe the remedy.

CAUSES OF VITIATION.

As proof of certain chemical changes we have the investigations of Professors v. Esmarch and Nussbaum. The former authority has demonstrated the following points:

Dust, especially when of organic nature, will decompose on heating surfaces from a temperature of about 160 deg. F. upwards. Of the gases produced, ammonia is shown by chemical reaction, not only over the radiator, but in the room air at large. The quantities are usually too small to be called a poison to the average person, but are quite often noticeable by odor. Under extreme conditions, when steam is turned into a dusty radiator or stack, the ammonia may become very disagreeable. Analysis was made for CO, but none could be found.

When heating surfaces were carefully cleaned before the test, the effect on the air was still present and demonstrable by analysis, but less intense, thus showing that the dust suspended in the air will also decompose when passing over the heating surfaces, and that there is a constant vitiation going on beside the periodical effect while reheating. No traces of any foreign gases could be detected until steam was turned on, hence we are safe in saying that heating is the cause. We may conclude also, that if heating were accomplished by clean surfaces and without causing air circulation, decomposition could not take place.

Prof. Nussbaum, investigating independently, has arrived at the same general conclusions, but has gone further into certain details. He found that moist organic dust will begin to decom-

pose even at 140 deg. F., while dry dust, or dust in dry air, must be heated to about 200 deg. F. before gases become noticeable. The same applies to dust lying on surfaces or passing by them.

Various kinds of dust were subjected to the tests. Inorganic matter was found to produce the least odor and practically no gas, while ordinary house dust, as it enters into rooms from the streets, with the air or by way of shoes and clothing, produces most of the ammonia. This is explained by the large percentage of animal excreta which ordinary street and house dust contains, particularly in cities with non-absorbent pavements.

Another indication of chemical reaction was furnished unwittingly, incidental to certain tests of ozonizing apparatus. It appeared, that the output of ozone was always reduced when the air was allowed to pass the electrodes slowly and to become heated thereby. The tendency of the ozone to combine with organic matter increases with temperature. Hence a good portion of the output was always absorbed even while the air to be ozonized was passing the generator. When slowing down the air current and raising its temperature, a point was reached at which no more ozone could be found in the air issuing from the apparatus. The temperature rise in such devices is much smaller than is usually the case with heating. Furthermore the surfaces for heating are much larger and less apt to be clean. We are safe in assuming that no ozone will ever get past a radiator or stack. It is most probable, that a certain amount of oxygen is also sacrificed by the process of heating, but the extent of this has not been established. In any event, the absorption of ozone, which may be said to be the sweetening, purifying element, would account in a measure for the lifeless quality of air issuing from a register or ascending from a radiator.

To prove certain physical changes in room air, it is only necessary to recall the long established facts, that fog and cloudiness are largely caused by dust and soot and that the relative humidity, at which condensation becomes visible, is much dependent on the purity of the air. This shows that moisture has a distinct tendency to cling to dust and weight it down, more or less, according to atmospheric conditions.

There is no doubt, however, that this moisture is evaporated when dust is being heated. It is lightened thereby and all the more easily joins the current of warm air rising from a heater.

The continuous air circulation incidental to heating keeps a certain amount of dust in motion, which would otherwise settle down, and will therefore add certain elements to the air we breathe.

Dust contains all sorts of impure, undesirable matter, causing stuffiness and undefinable odors. In dried, partially decomposed condition it is extremely light-winged and penetrates everywhere. It will penetrate textiles, wall papers and make itself felt by odor even after its removal from the surface. Eminent hygienists have long since agreed that dust is the principal carrier of bacteria which attack our respiratory organs. Dr. T. Mitchell Prudden, among others, has brought out the situation clearly in his treatise on dust and its dangers. It is by no means likely, however, that these live organisms are destroyed to any extent by the ordinary forms of heating apparatus. This depends on higher air temperatures or on steam itself. Furnaces, except in red-hot condition, which is undesirable in other ways, and radiators, therefore, cannot be considered as sterilizers. They merely dry the dust, stir it up and turn it from a latent source of danger into a patent, active agent of infection. Considering this, we are forced to admit, that heating increases the bacterial contents of the air. The fact that sometimes the exhaust from heated and ventilated rooms shows less bacteria per cu. ft. than the incoming fresh air proves nothing, except possibly that the bacteria is not so apt to settle down on the test surfaces when the dust is dry and kept in circulation. It is possible, also, that a considerable percentage finds its way into the respiratory organs of the occupants of the room, instead of settling down and being removed in other ways.

To define certain differences of a purely thermal nature, it may be useful to remember, that all forms of heating, or broadly speaking, of creating comfort indoors, depend more or less on the utilization of air as a heat carrier, but the more the radiant heat is utilized by the apparatus the less we depend on the air circulation. The feeling of comfort could be created almost entirely by heat rays, if well distributed, with the air temperature much below the customary 70 deg. F. We need only recall a clear, sunny, still day in the winter, especially in a dry country, high above the tide, where cold does not seem to exist until the sun sets.

The opposite extreme in warming is reached by a heat source outside of the room, for instance a furnace, indirect stack, or screened radiator, imparting no direct heat rays, but depending on air circulation alone. In that case the incoming air must necessarily be above the room temperature desired in order to convey sufficient heat to the structure to make it feel comfortable. This results naturally in higher mean *air* temperatures and lower mean *wall* temperatures. In massive buildings, where the thermal loss per hour is small, this condition is not felt to any extent, except during the period of reheating, but where the heat transmission is considerable and large volumes of very hot air must be used, the *air* temperature at which the room is comfortable must be decidedly higher, the relative humidity correspondingly lower, and likely to be reduced further through excessive renewal which carries away the ever-present equalizing and regulating internal sources of moisture. In other words, hot-air heating under such conditions dries out the building and contents to an undesirable degree. The room air is drier and the air temperature distinctly higher than would be the case under the application of radiant heat with liberal leakage or direct, natural window ventilation.

Summing up these different causes, we may say, that chemical adulteration is shown by the addition of ammonia in appreciable quantities and the probability of other products of decomposing organic matter, also by the elimination of ozone and probable reduction of oxygen.

There is also an admixture of dried dust, kept in circulation by heating apparatus, which involves also an undesirable addition to the normal bacterial contents of the air.

It has been attempted to show also that, what might be called the purely thermal changes incidental to heating, may differ materially according to the style of apparatus and will modify more or less the condition of the room air.

EFFECT OF VITIATION BY HEATING.

This general analysis would seem to leave no doubt of the fact, that room air is more or less vitiated through certain methods of heating as now generally applied, but the exact consequences are more difficult to establish. We have to resort here to the

same sort of common sense and philosophy as in questions on the effect of foul air and lack of ventilation, which are themselves difficult to define by test, though admitted to be a reality.

Of the chemical adulteration, the presence of ammonia may become distinctly objectionable where the heating surfaces are at high temperatures and are not kept clean, and where a considerable amount of street dust is present in the air. It will be admitted, that these conditions often maintain, especially in public buildings and conveyances.

The elimination of the ozone and whatever loss of oxygen may occur probably have no distinct and traceable effect on health. They represent the general drawback of indoor life, not serious in itself, probably because we have long since become inured to it. The situation is different in regard to the contamination of the air by fine, dried dust, which has become general more recently, through prevailing methods of heating. This may be clear if we remember, that the old-fashioned tile oven, the ordinary free standing, well-polished, iron stove, or the open fireplace depend on their effect largely on radiation, and that the heating surfaces are readily accessible and apt to be clean. This cannot be said of the hot-air furnace, nor of indirect stacks, nor of certain styles of radiators, and least of all of the screened direct surfaces.

While the public may have become indifferent to the immediate sensible effect of dust contamination, because it is so general, it is nevertheless a real nuisance. The prevalence of chronic ailments of nose and throat would indicate that we are not immune to it. It is one of those elements which have eluded the ordinary air tests made with the idea of determining the need of ventilation, and did not exist to any extent at Pettenkofer's time, when the carbonic acid test was recommended. Naturally, it would not show in this sort of test. Nor would a bacterial test be fair, since the dried particles are not so apt to settle down on the surfaces prepared for them as ordinary, unheated dust would do. If the lessons to be drawn from the campaign against tuberculosis and modern hygiene in general are of any value, we must admit that this flying dust is most undesirable. It irritates the mucous membrane, congests the respiratory tract and thereby creates at least a predisposition to disease. It is more than likely that it also increases the chances of infection, although this would be more difficult to demonstrate, since the consequences of such in-

fection are never immediately apparent. Although they are by no means always resulting in disease, the known facts would seem to justify the conclusion, that infection is encouraged and the chances of spreading disease are increased, especially by certain methods of heating which turn the latent danger of house dust into an active agent of infection.

As to the bearing of the purely thermal quality of the air, we can only judge by general experience. It is true, overheating has been shown by Fluegge to cause a distinct lowering of vitality. The question is not really one of overheating in this case, but whether radiant heat with comparatively low air temperature, or higher air temperature without heat rays, are more conducive to comfort and health, and whether the latter tendency produces effects similar to overheating.

Aside from the direct bearing of the hot-air currents on the dust, we have to consider the lower relative humidity of hotter air and its greater drying effect on persons as well as on dust and other objects, caused partly by the air in transit, and in the neighborhood of the register. All things considered, there would seem to be no question that the excessive dryness which is often complained of in heated rooms is materially increased by those methods of heating depending on air as the heat carrier, and is made more irritating by the attendant increase of dustiness.

There is also the general observation that cool air is breathed in more freely. This may be partly due to the feeling that it is more inviting, because less apt to be contaminated. We are certainly more apt to take a deep breath of fresh air than of foul air. Again, there is also the purely physical condition of its smaller volume for the same amount of oxygen, causing less labor in respiration, even though its final temperature may be the same. Most persons have more difficulty in getting their breath in hot air than they do in cold air. Whatever may be the contributing causes, the great majority of people would certainly prefer a quality of room air that approaches the ideal weather conditions of a cool, bracing atmosphere, with sunshine, rather than a hot and dusty wind on a cloudy day which are the uncomfortable, uneasy forebodings of a storm.

If there is anything in the theory that free air circulation around each person is a most desirable element in creating comfort, regulating the thermal formations of the body and conserv-

ing health, cooler air surrounding a body would seem to be more likely to induce this in the natural way than warmer air would do. The currents created by a hot-air heating system generally do not take place where such circulation might be wanted. Hot-air heating therefore would tend to reduce the convection of heat from the body which Fluegge claims to be a necessary function in maintaining health and comfort.

These last remarks do not belong to the question of dust, but to the various effects of heating on air. Briefly reviewing these effects, it may be stated, that in a similar way, like those attributed to foul air they are not only due to a variety of circumstances and causes, but have a most variable effect in degree, and furthermore do not by any means affect all persons alike. The results of a series of tests by a single professor on a single or a few individuals, in one phase alone, should be accepted only for what they are worth. To reach a general conclusion we need a broader view, taking in all the doctors, as well as the public, the investor, and the experienced engineer and then use some common sense.

It is well known, that the vitality or nervous reserve force of individuals varies within the widest limits. The strong, healthy outdoor man can endure almost anything in the line of the most wretched ventilation and heating our profession has ever devised, or failed to cure, and for an indefinite length of time. The yellow races can get over almost any kind of infection that would kill the white, red and black. Some will endure cold, others heat and still others dryness and moisture. What is meat for one is poison for another. However, the average city dweller and business man with a load on his brains has much less energy in reserve, he is more predisposed for disease, and has generally less powers of resistance than the outdoor man. When caught in poor condition he will be depressed by foul air, predisposed to disease and exposed to infection through unsanitary heating or lack of ventilation. In the light of these reasons we need not be so much concerned over the healthy and the average man who takes care of himself, as with the great mass of people who have little energy and vitality to spare, and whom we should seek to give an equal chance in life, rather than to handicap them. Among these are the numerous persons affected with ailments, chronic and temporary, also the poorly nourished among the

children at school and many others, whose margin of vitality is very small and easily wiped out by adverse conditions. These are easy victims to foul air and infection caused by inhaling dried dust.

There is also a duty imposed on public institutions, educational and others, who are presumed to take the best care of their charges which include the weak and strong and have no right to tolerate any preventable unsanitary condition.

Last but not least, we must take care of the sick, whose vitality is already below par and who must not be put under further disadvantage.

Vitiation of air by heating, although a handicap to any person is therefore not a serious matter for the healthy, but a distinct source of danger to a great number of people. All classes of apparatus produce it to an extent, but considering the causes, it would seem to be more serious with some of the prevailing modern methods of heating than with some of the old devices that have survived. It depends much on the maintenance of an apparatus and is felt more at certain times, but is probably just as general, if not more so, than poor ventilation. It is worth while to see what can be done to remedy the situation.

MEANS TO PREVENT VITIATION BY HEATING.

Naturally, the foremost remedy that suggests itself is to exclude the dust, as the main source of vitiation. We all agree this would be desirable, but unfortunately it cannot always be done. Even where artificial devices for this purpose are used in connection with warm air heating and air supply systems more or less dust will enter into a building in other ways. Vacuum cleaners and general vigilance will help, but the fact remains, that in a great majority of cases we will have to contend with more or less dust, and must proceed on this assumption.

The safest way to prevent the chemical adulteration of air through decomposing of organic matter would appear to be a moderate temperature of heating surfaces. With clean surfaces and dry air, according to Nussbaum, there will be no vitiation with temperatures up to 160 deg. F., and none to speak of until the surfaces are near the boiling point. Under less ideal con-

ditions, when more or less dust is to be expected, the temperature should be kept down to about 160 deg. F. or lower, as a rule, accepting an occasional rise to 180 deg. F. during a cold spell as unavoidable and of minor importance.

Moderate temperature of heating surface seems also advantageous in view of the devitalizing of the air by the absorption of all the ozone and probably of part of the oxygen.

To avoid the contamination of room air by dust, whether in dried, decomposed, or normal condition, it would seem advisable again to heat at low tension, which means liberal surfaces at relatively low temperature. Low and shallow styles of radiation, depending the least upon convection, are also indicated. Even with equal air volumes in circulation, the movement will be less concentrated, less intense, and less apt to pick up dust. It may be well to distinguish here, that air circulation created by heating is not the kind which is useful from a ventilating point of view. No matter what may be our final judgment in regard to secondary circulation, or the desirability of a certain movement of air around the bodies, it should still be our endeavor to prevent or distribute as far as possible, all sensible air currents by heating. They are likely to be either too hot or too cold for comfort and not apt to occur where they might be needed.

Hot water heating would seem to meet the situation best in respect to temperature and liberal surfaces, but whichever system is used, it is advantageous to reduce the tendency to create air currents and to give preference to the kind of surface that is yielding a greater ratio of its heat by radiance. Low and flat radiation which is recommended is generally no more expensive considering its higher total efficiency.

The next important rule should be to insist on clean heating surfaces. It will not do to depend for this on the good intentions of any one concerned. Engineers must take the first step to induce or compel clean surfaces by selection of the most easily cleanable styles and by proper disposition to keep the greatest part of it in view. As it happens, the styles which are giving the best radiant heat and the least contamination by dust are also the easiest to clean. Radiators should have fair spacing between loops to show the dirt and to make it likely that it will be removed. They should not be tucked away in corners. Better

means are always at hand to make them inconspicuous or presentable, as the case may require. Enamel finish in some neutral color, black or white, is only one of those means, which, by the way, will help appreciably in the radiating efficiency. This sort of finish, it is sometimes complained, would show the dust. It is all the more desirable then, in order to induce clean surfaces.

One of the common causes of air vitiation is the regrettable practice of screening direct radiation. No matter how easily removable, the screens will never be cleaned out regularly and often enough unless the dust is *seen*. While it is not seen it will never be taken care of *properly*. Screens are utterly false, from every point of view. In heating matters to-day, the engineer is the true judge, not the architect who rarely understands the underlying principles. Of course, both should be satisfied with the solution of a problem, as a whole. But while we might be justified in giving way to the architect's desire if it were only a foolish expenditure, or a question of taste, we ought not to submit to dictation on an issue of sanitation against decoration. Dirt pockets are undesirable anywhere as a latent danger to health, but more than undesirable in connection with heating, which turns them into potent factor of pollution by communicating the dirt that is in them to the room air in the very form in which it is most apt to do harm. Even at best, assuming that the surfaces were kept clean, screening turns a direct system into hot air heating by rotation, that is, in its least desirable form, but we have no reason to assume that they are kept clean. There are always other means and solutions possible and acceptable from our view point as well as that of our artistic friends. It would be going too far to discuss these at this time.

There are a number of other practices, which in the light of the foregoing should be classed as unsanitary.

It is unsanitary to place heating surfaces overhead, where the dust is not seen and rarely removed, except by air currents.

It is unsanitary to run pipe connections to radiators in a roundabout fussy way that will make dirt corners.

It is unsanitary to use floor registers for heating under any conditions.

Similar features and practices that may appear questionable from these viewpoints may be tolerable under some conditions, but objectionable in other places. One should use judgment and

discretion in this respect. In hospitals, for instance, a stricter standard should prevail, also in public buildings where the service and maintenance are not of the best.

For years we have enjoyed clean plumbing fixtures, designed on hygienic lines, and insisted on cleanliness in many other ways, if only on general principles. There is every reason why we should insist on the same qualities in heating equipment, which is now nearly always on a decidedly lower plane in this respect than other apparatus in one and the same building. Enameled radiation would be produced, if there were a serious demand. The better styles of radiation are true and good in design, but usually false and mean as to finish. The best finish enamel is the most sanitary, and in its turn would encourage proper self-assertive disposition in place of the unfortunate habit of hiding. Substantial appearance and neatness in details will also help in this direction.

If it be conceded, that cooler air, combined with mild radiant heat is the desirable, pleasant atmospheric condition to be reproduced indoors by artificial heating, we come again to the same conclusion in regard to the methods. Flat, low, widely spaced direct radiation at moderate temperatures would evidently give the nearest approach to it, when combined with whatever ventilation that may be desired, direct by leakage, by windows, or by a clean, evenly and low tempered air supply system. Indirect or hot air heating should be used only where the heat requirement is comparatively small, that is, in substantial buildings and in rooms with moderate exposure, for which the incoming air for heating need not be much above room temperature. In exposed buildings of light or permeable construction hot air heating in any form is not only uncertain, inefficient and undesirable on account of the dust pollution, but it will involve high air temperature with colder walls, lower relative humidity, especially as a structure becomes dry under the active ventilation. Again, in massive structures, with little exposure, there may be good reasons for some artificial air supply, while natural leakage is often all that is necessary in buildings requiring much heat.

Considering, that the requirements for heat and for ventilation generally are not all coincident, and that a purer, more effective and wholesome air supply can be secured by windows or other rational means, when and where required, and without af-

fecting the heat supply, it would seem that the idea of better sanitary conditions through heating by air is largely a delusion. The indirect method should be restricted to cases where it is really indicated, or, if no other system will do, the conditions might be made more favorable for it by extra protection. In any event, such apparatus should be designed to avoid excessive air temperature, equipped with filters to keep the dust out of air passages and heating stacks, and with all provisions to induce proper maintenance of the apparatus.

In so far as excessive dryness in itself, as caused by heating, may be undesirable and unwholesome, it is pertinent to consider also the best means to overcome these extremes. As previously pointed out the method of heating in itself makes an appreciable difference and would seem to be the natural remedy, under ordinary conditions and for new apparatus. To relieve an old plant it may be necessary, sometimes, to use artificial moistening, but when doing so it should be borne in mind, that moistening without taking care of the dust is liable to increase discomfort through the increased decomposition of organic matter. The rule should be to moisten only when the air supply can be filtered or washed.

The excessive dryness complained of sometimes with direct steam heat is often nothing but irritation of the respiratory tract through dust. It should be relieved in such cases by cleaner radiation and cleaner surroundings, and by lower temperature of heating surfaces. Moistening pans will raise humidity, but generally they do not improve the air while dust and dirt are present.

If it is recognized, that air is vitiated by heating apparatus, it will be admitted, also, that the quality of the air may be affected by apparatus designed purely to ventilate, in particular those parts intended to temper the air supply, and to distribute the same. Complaints of this nature have been heard, but such effect has not always been admitted and rarely traced to its true sources. Whatever may be the exact bearing on the sweetness and purity of the air, a supply system, on general principles, should be clean as a whistle from the intake to the register and give no chance for contamination of the air in the transit. To this effect it is most desirable to design the duct system to be self-cleaning, by avoiding chambers, pockets, sharp turns and all

opportunity for eddies where dirt and dust will lodge and dry. Wherever necessary, the air should be filtered or washed near the intake.

The tempering surfaces should be arranged to secure a swift passage for the air and designed also with the idea of making them self-cleaning, and to reduce the chance of drying and decomposing dust in transit. Present styles of tempering stacks and coils are by no means ideal in this respect. They could be much improved in the direction of higher velocities and heating efficiency without necessarily increasing resistance.

As an interesting fact it may be stated, that the most efficient air supply system from the mechanical point of view, which is one designed on true aero-dynamic principles involving the least loss of motion, is also by chance, or by a deeper truth, the ideal one from the sanitary point of view. The same is true, at least in a measure, with heating apparatus. The most efficient apparatus, mechanically, is direct heat, which certainly permits the most advantageous distribution and application, bearing on efficiency. In hot air heating, for instance, a large percentage is lost, not only through the incidental ventilation, which is not always needed, but through the inability to place the heat where most wanted, which involves overheating. Much heat is wasted also through the tendency of the warmed air to escape by overhead leakage. Hot water heating is recognized to be more efficient mechanically in various ways, and surely is preferable from the sanitary point of view. Clean heating surfaces are more efficient than dusty ones. Finish of radiation in enamel, that shows the dust and induces cleaning, is also distinctly better for heat emission, according to Prof. John R. Allen, than the bronzing. The practice of screening direct surfaces is the most wasteful and inefficient way of heating, is also the most objectionable hygienically.

These would seem to be sufficient reasons for reform, and the lines on which to improve heating apparatus from the sanitary point of view do not seem difficult to follow and would lead, if anything toward greater efficiency in other directions. Nor should there be much difference in cost, when taken as a whole. Hot water heating, for instance, can be brought down very nearly to the cost of steam, if scientifically planned, and the practical possibilities of its adaptation to all sorts of conditions

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are by no means exhausted. The ways and means for reform may therefore be said to be within our reach.

Briefly resuming we may put down the following rules, which may serve also as a guide in the event of a discussion:

1. To prevent chemical vitiation of room air by heating it is desirable to have heating surfaces at moderate temperature, if possible not exceeding 180 deg. F. at any time and to use easily accessible and clean radiation. Air supply should be filtered where necessary.

2. To prevent the physical admixture of dust and its drying, caused by the air currents due to heating, it is desirable again to use heating surfaces at moderate temperature, well distributed, spread out and inducing salubrity in general.

3. To reduce the pollution of the air by the bacteria the same means are indicated as those recommended to keep down the dust.

4. To produce thermal conditions most agreeable and wholesome to a majority, it seems desirable to favor the application of radiant heat which warms the surroundings and occupants directly and produces comfort at lower air temperature. It should be used in a mild form and be well distributed. Ventilation should be treated as a separate problem, as each can be solved by itself to the best advantage.

5. To prevent excessive dryness, the same idea of keeping down air temperature by utilizing heat rays seems indicated.

6. Ventilating apparatus should be made self-cleaning throughout.

DISCUSSION.

Mr. Barron: I would like to have some of our members who are interested in the paper say a few words upon it. I think it was a valuable philosophical paper and there should be some discussion on our record. If the paper passes through here without discussion I am afraid any student who reads it would get a false impression, that is, that we all agreed with the author's philosophy of life. My recollection is he assumed a great many things in the paper. He assumed that low temperature and hot-water heating and direct radiation on general principles are the best, which is not true, speaking generally. Then he assumed, which was a philosophical assumption, in regard to nature's pro-

vision for eliminating the unfit, that it is desirable that we act against it, an unusually broad assumption; in other words, he took the very general assumption of medical and scientific societies that our duty as heating engineers is the same as theirs, in a measure, that is to work in co-operation to remedy the various evils that are caused by dust and other evils, that of intemperance, for instance, and all that sort of thing, which may be philosophically wrong. Those assumptions, I think, if the matter had been generally discussed, as was formerly the case with individual papers, would have brought out contradictory views; I think the philosophical points of this paper would have been emphasized; but it would be better for the students who came afterwards to reject what the biologist questions and merely to read the statement of facts, because it was really a very valuable paper, and should be criticized.

Mr. Ralph C. Taggart (by letter): Mr. Meier in his paper, "Dust in Relation to Heating," has said many good things. He has, however, in some cases made assumptions concerning which I believe there is considerable doubt and in a few cases he has made statements with which I cannot agree.

He makes a special point of the decomposition of certain dust on heating surfaces at temperatures as low as 160 deg. F. No one certainly will argue against the elimination of dust in so far as possible. Before condemning heating surfaces, however, with temperatures of 212 deg. F. or thereabouts (low pressure steam), we should consider what is the real extent and effect of the decomposition or oxidation referred to.

The decomposition is especially objected to by the author because he says ammonia is produced and although he says that the quantities of the ammonia are usually too small to be called a poison to the average person, he claims nevertheless that they are quite often noticeable by their odor.

I must disagree with the author as to the noticeable odor of ammonia, said to be quite often produced by radiators. I have seen many radiators without finding such a case or meeting a person who has had such an experience, although ammonia is a very penetrating gas and easily detected by its odor.

There is one point, however, in this connection which has not been mentioned in the paper and that is the fact that the temperature of the air heated by a radiator does not reach as high

a degree and often not anywhere near as high a temperature as the radiator itself. This is true both of direct radiators which are located within the living rooms and also of indirect radiators which are not themselves located within the living rooms.

In the case of indirect radiators the temperature which the air will reach (whether we consider the average temperature or only the temperature of the air which passes close to the heater), will depend very much upon how fast the air passes the heater. It is possible, therefore, by having the air move rapidly past a short length of heater to have the temperature to which the air is heated kept down to almost any desired point.

Where a building is ventilated by a fan system it is possible also to eliminate nearly all of the dust by air washing, and we can then raise the temperature of the air as little as desired, even though the heating surfaces are at the temperature of low pressure steam.

It appears, therefore, that there can be no practical injury to this air by decomposition, due to the temperatures of low pressure steam.

In regard to the question of the lessening of the oxygen content of the air, an investigation will show that, if all possible oxidation takes place in ordinary air (and especially in air that has been washed) the loss in oxygen will be absolutely negligible.

In so far as ozone is concerned there is still a difference of opinion as to the good results from ozone in the air. We know that too much of it is bad. A little of it, if nitric acid or nitrous fumes are not produced simultaneously, may perhaps be desirable or at least be unobjectionable.

A curious side light on the subject may, however, be gained from the fact that one of the principal reasons for the use of ozonizing apparatus, as advocated by some of its leading exponents is the fact that ozone will aid in the oxidation of dust particles in the air,—the very thing that is held as objectionable in the paper under consideration, and if ozone "may be said to be the sweetening, purifying element" of air, as stated in the paper under consideration, it would appear to be simply a result of its activity in producing oxidation or decomposition of dust particles, etc.

The author also refers to the fact that hot electrodes in electric apparatus prevent the production of ozone and he, therefore, argues that no ozone will ever get past a radiator or heater. This, however, does not seem to be a convincing argument, even if we grant that ozone is desirable.

In the production of ozone the action is at the electrode terminals and when they get hot the temperature at the point of activity is likely to be much higher than is ordinarily appreciated and higher than an ordinary testing instrument will show, as will be appreciated by anyone who has had much to do with temperatures in electric apparatus under such conditions.

In the case of ozone passing through an indirect steam heater, however, a great deal of the air does not come in contact with the hot surfaces, so that much of the air is heated no hotter at any time than the final temperature of the air, and, even if we assume that the hot surfaces break up the ozone it is possible to so arrange the apparatus that the larger part of the air may be heated very little above 70 deg. F., and cannot therefore lose its ozone from overheating, in which case the total bulk of the air need not at the most lose more than a small part of its ozone.

In so far as the sterilization of air in heating apparatus is concerned, the author is probably right in saying that sterilization requires higher air temperatures than those produced in the usual steam-heating apparatus, and yet we must not forget, if we talk of heating air to 160 deg. F. or higher, that in pasteurizing milk so as to render it immune from harmful bacteria, a temperature of 160 deg. is held to be ample.

In the matter of direct radiation, the author of the paper apparently thinks that it is desirable to increase the direct radiant effect of the heating surfaces and lessen the heating of the air. In this connection it might be pointed out that the proportion of the total heat given off by steam radiators as direct radiant effect is larger than in the case of similar hot-water radiation at a lower temperature, and steam radiators would in this respect nave some advantage over the cooler surfaces of the hot-water radiation.

Mr. Konrad Meier (by letter): It would appear that certain points in my paper, "Dust in Relation to Heating," have been misunderstood by Mr. Ralph C. Taggart and may require further explanation.

That organic dust will decompose on heated surfaces at temperatures of 160 deg. F. and upwards, has been sufficiently demonstrated. When steam is turned on a radiator after a considerable interval, the odor of ammonia, although mixed with other gases is often noticeable, but its source is usually not recognized. More frequently the odor is not distinct, the effect being merely a stuffiness. This is partly caused by the drying of dust which makes itself felt at once to some persons by irritations of the mucous membrane. While the layman will not always find the cause of the dead air, a trained hygienist or a heating engineer should be able to detect and trace this sort of vitiation.

The air leaving a radiator is a mixture of warmer and colder streams. It is not its final temperature, but *that of the heating surface itself* which will affect the dust which has been allowed to settle on radiation or comes in contact with it.

When a building is heated by forced air currents, through a central heat source, there is little objection to higher surface temperature, as applied with steam heat, if the air is filtered, washed and the surfaces are self-cleaning. Filters and washers are not always available and the types of blast surfaces now on the market give still too much opportunity for dirt to collect behind stoppers, between nipples and section at bottom of casings. The typical indirect stacks under natural draft also gather dust, mostly on top, out of the air current, but nevertheless giving opportunity for decomposition and drying. Low temperature of surface is therefore preferable for indirect heating as well.

While the products of decomposition are disagreeably felt, and the loss of ozone, and probably oxygen, take at least the sweetness out of the air, if not more, it has always been held that these factors are of less importance than the drying of the dust which goes on continuously, more or less, and keeps the irritating disease-bearing elements in motion. Hot, dusty, screened and inaccessible surfaces, which depend on or produce more air currents are undesirable mainly for this reason.

As to the temperature at which air would be sterilized it is well known that dry heat must be considerably above the boiling point, while germs in liquid or in steam are killed at lower temperature.

It will be conceded that the free, natural ozone in the air is naturally beneficial. Artificial supply of ozone should be beneficial also, at least in so far as it *consumes* the organic dust and other noxious matter and thereby deodorizing and sweetening the air. This has been demonstrated. Heating radiating surfaces, on the other hand, will only *decompose,* or cause the dirt to rot, *to dry, to mix with the air* we breathe and *to vitiate* it. Ozone *sterilizes* the air, but is consumed thereby. This accounts for the reduced output of ozonizing apparatus where electrodes are hot and allowed to gather dust. Likewise the disappearance of the natural ozone when it passes a radiator is explained, there being not nearly enough free ozone, as a rule, to absorb the usual amount of dust on heating surfaces. "Canned air" is the result of high surface temperature combined with the typical insalubrious, unhygienic styles of radiators, methods of heating, and arrangements of apparatus.

The utilization of radiant heat *in mild form* has been recommended because it favors exposed, clean surfaces, giving least air currents and approaching the effect of the natural heat rays of the sun. The latter are generally agreeable in winter, but may become most uncomfortable and even fatal in summer. With steam heat, likewise, the radiant heat in most cases becomes too concentrated, too intense. Moderate temperature of heating surface seems therefore desirable from every point of view.

CCLXXV.

RELATIVE HUMIDITY

ITS EFFECT ON COMFORT AND HEALTH

BY J. I. LYLE.

The anti-tuberculosis movement of the past few years has done more than anything, and probably everything else to impress the general public with the dangers of contagious diseases being procured from dust. There has been a growing demand for better means for dust elimination, and the engineers to meet this demand have installed air washers for those plants provided with mechanical ventilation. In fact, the use of air washers has grown very rapidly and to-day it may be said that their installation is almost universal in the better class of plants.

With the development of the air washer, simple methods for accurate humidity regulation have been developed; not makeshift arrangements that had been used by some in the past, but methods remarkable for their simplicity and reliability. There have been many references in the magazine articles and the technical press to the advantages or disadvantages of humidifying.

Very naturally the question of what is the proper relative humidity best adapted to health and comfort has been presented to everyone concerned with ventilating installations. The author has been asked that question in some form or other probably oftener than any other, so when he was asked to present a paper on the subject, although the time was exceedingly short and he felt he could throw but little light upon it, he trusted that the facts and references presented would be such that a general discussion would follow. There is as little hope that we can agree upon this subject as upon any other, and probably less; still, we will have the pleasure and derive the

benefit from hearing the other fellow's ideas, and of his experience.

What is the effect of humidity upon the human body? But immediately this opens up many other avenues of thought such as:

Is it absolute or relative humidity that does affect our sensibilities?

Is the wet bulb temperature the controlling factor?

Do we need high, moderate or low humidities?

Does change in temperature alter the effect of humidity upon the body?

Is a constant humidity desirable throughout the year?

What is the effect of the shock in passing from one condition of temperature and humidity to an atmosphere having different conditions?

Our bodies have very aptly been likened to furnaces in which a food is burned producing a varying amount of heat, which must be dissipated and the proper regulation of the loss of this heat is probably the most important factor in producing bodily comfort. This heat must be extracted in three ways; viz., *Radiation;* which varies directly as the difference between the temperatures of the body and the surrounding atmosphere. *Convection;* which varies with the velocity or movement of the air, and the difference between the temperature of the body and surrounding atmosphere. *Evaporation;* which varies with the amount of moisture brought to the surface of the skin through the pores, with the velocity or movement of the air past the surface and the depression of the wet bulb temperature below that shown by the dry bulb thermometer.

Is artificial humidity desirable?

This is a question not for the engineer but for the medical fraternity to answer. The engineer's province is to provide apparatus, appliances or means to furnish the results which the physicians specify.

But few of us ever realize what is good for our bodies. It takes a lot of preaching to arouse the lay mind to any danger to his health. In fact, it takes a lot, it seems, to arouse some medical minds. As to comfort, however, any one of intelligence can testify.

The author wishes to quote from the following gentlemen who have studied this question from various view points:

Dr. Henry Mitchell Smith, in a paper read before the Brooklyn Medical Society, entitled "Indoor Humidity," says:

The point to be emphasized is that every time we step out of our houses during the winter season, we pass from an atmosphere with a relative humidity of about 30 per cent. into one with a relative humidity of, on an average, 70 per cent. Such a sharp and violent contrast must be productive of harm, particularly to the delicate mucous membranes of the upper air passages.

The skin and the mucous membranes of the respiratory passages are the principal sufferers, since these tissues are always kept moist with their own secretions and from them water is freely abstracted to satisfy this large saturation deficit, such air passing with every inspiration over the moistening surfaces nature has provided in the mucous membranes, calling for an enormous output of the fluid elements of these tissues. This leads to glandular over-activity and its consequent evils, the elaboration of which subject the scope of this paper does not permit.

The overheating of our houses has been accepted as a prominent cause of "catarrh," but I am confident that the low relative humidity and consequently the large saturation deficit of the aqueous vapor in the atmosphere of our rooms in winter is much more important than is the overheating in itself, and it may be doubted whether the so-called damp climate of the sea coast or the shores of large inland lakes is in itself so responsible for the above diseases, as has been generally supposed. It seems much more likely that the great contrast between the indoor and the outdoor relative humidity in those regions is the real factor.

If our rooms contained more moisture we could live more comfortably at a lower temperature. The overheating is required because of the low relative humidity.

It is unscientific and arbitrary to lay down a fixed temperature as a standard for living or sleeping rooms unless the relative humidity is indicated as well.

These tests were most instructive. In the first place it was observed that with a proper percentage of moisture 70 deg. F. was uncomfortably hot, 68 deg. F. warm, and 65 deg. comfortable. By proper percentage of moisture is meant one which is never below 50 per cent. or above 70 per cent.—average about 60 per cent.

The former (65 to 68 deg. and 60 per cent.) felt warm and balmy, the latter (72 deg. and 30 per cent.) notwithstanding the higher temperature, chilly and dry, and the slightest motion of the air suggested a search for the source of suspected draughts.

There is an indescribable sense of relaxation and "poise," contrasting strongly with the feeling of nervous tension so frequently experienced in overheated dry rooms.

It was satisfactorily proven that one may live during the coldest weather with perfect comfort in a room at 65 deg. F. where the relative humidity is kept at about 60 per cent.

During the experiments upon the sensations produced by different percentages of saturation and in order to obtain the opinion of persons having no knowledge of the existing conditions one room was equipped with a moistening apparatus and the temperature kept at 65 deg. to 68 deg., with a relative humidity of about 60 per cent. An adjoining room, without a moistening apparatus and heated by an ordinary steam radiator, had an average temperature of 72 deg. to 74 deg., with a relative humidity of 30 per cent. In every instance, and without at all knowing what the temperatures were in the two rooms, the opinion was unhesitatingly expressed that the first room was several degrees warmer than the second.

During my experiments it was very noticeable how much more uniformly heated seemed all parts of the room in which there was sufficient moisture than when no moisture was artificially supplied. Under ordinary conditions of heating the uncomfortable difference in temperature between the parts of the room that are near and those that are remote from a radiator is a familiar experience.

It is easier to "take cold" in a room at 72 deg. with a relative humidity of 30 per cent. than in a room of 65 deg. with a relative humidity at 60 per cent.

Generally speaking, dry air is an excitant often causing sleeplessness and irritability, accompanied with a drier skin and quickened pulse. Moist air is more of a depressant, producing quiet sleep and slower circulation of the blood.

After living in rooms with a lower temperature and proper relative humidity no one will be satisfied with the other conditions.

Prof. C-E. A. Winslow, associate professor of biology, College of the City of New York, and Curator of Public Health, American Museum of Natural History, in his paper "The Scientific Basis for Ventilation Standards," states:

The really important factors which make for health or disease in the atmosphere are physical rather than chemical or bacteriological. From this standpoint the effect upon vitality is great, not only of the air we breathe, but of the air which surrounds our bodies. . . . It is not the quantity of air or even the quantity

of "fresh" air that is important; it is the physical quality of the air in its relation to the human body that is significant. Our ideal must be the conditioning of the air so that the human machine may operate at the highest level of health and efficiency.

The chief factors in air conditioning for the living machine, which in most cases far outweigh all others put together, are the temperature and humidity of the air.

Again he says:

If the temperature be maintained between 66 deg. and 70 deg. a relative humidity of about 70 per cent. may be considered as a maximum beyond which it is undesirable to go. A lower limit may perhaps be tentatively set at 60 per cent., although it is not at all certain that the range might not be safely extended to 50 per cent. at the lower and 75 per cent. at the upper end of the range.

Again Prof. Winslow, before the Congress of Technology under the subject of "Factory Sanitation and Efficiency," says:

The main point in air conditions is, then, the maintenance of a low temperature and of a humidity not too excessive. For maximum efficiency the temperature should never pass 70 deg. F. and the humidity should never be above 70 per cent. of saturation. At the same time, a too low humidity should also be avoided. We have little exact information upon this point, but it is a matter of common knowledge with many persons that very dry air, especially at 70 deg. F., or over, is excessively stimulating and produces nervousness and discomfort. It would probably be desirable to keep the relative humidity between 60 and 70 per cent.

Prof. Theodore Hough, of the University of Virginia, in the American Journal of Hygiene, states:

This objection to low humidity is due to the too rapid evaporation of water from the skin and air passages. The skin thereby becomes dry and tends to chap, cutaneous nerves are irritated in an unpleasant manner, with more or less disturbance of affairs in the central nervous system. Especially the drying of the conjunctival and sclerotic seems to be a matter of considerable importance. I suppose, too, that when the skin dries too quickly there is greater tendency to the deposition of the solids of perspiration in the ducts of the sweat glands. These ducts are not flushed out as they should be.

Dr. William Moir, master in surgery, Doctor of Medicine (Aberdeen), Diploma of Public Health (Cambridge) in testifying before the Parliamentary Committee of Ventilation of Weaving Sheds, stated:

Personally I think that rheumatism—I do not mean acute rheumatic fever—but chronic rheumatism is much more likely to be benefited by a high relative humidity figure than otherwise; and bronchial cases benefit very considerably by going into a humid (atmosphere) more than if it were a dry one.

He further states that a humidity up to 88 per cent. would not be injurious.

In an article by Dr. W. M. Wilson of the Weather Bureau, entitled "Atmospheric Moisture and Artificial Heating," the following is stated:

The evaporation power of the air at a relative humidity of 30 per cent. is very great, and when the tissues and delicate membranes of the respiratory tract are subjected to this drying process, a corresponding increase of work is placed upon the mucous glands in order to keep the membranes in proper physiological condition, so that nature, in her effort to compensate for the lack of moisture in the air, is obliged to increase the functional activity of the glands, and this increase of activity and the frequent unnatural stimulation, induced by the changing conditions of humidity from the moisture laden air outside, to the arid atmosphere within our dwellings, finally results in an enlargement of the gland tissues, on the same principle that constant exercise increases the size of any part of the

animal organism. Not only do glands become enlarged, but the membrane itself becomes thickened and harsh, and sooner or later the surface is prepared for the reception of the germs of disease, which tend to develop under exposure to the constantly changing percentage of humidity.

It might be interesting to notice some remarkable cases which have come under observation where catarrhal troubles have been relieved and apparently cured by simply introducing sufficient moisture into the air to bring the conditions to something near normal.

Drs. Thos. R. Crowder, J. A. Denny, and C. A. Schroyer, as a Committee on the Ventilation of Cars, read in the section on Preventive Medicine of the American Medical Association at its 62d Annual Session held at Los Angeles, June, 1911, a report from which the following is copied:

When the humidity is low, or the air motion is great, a higher temperature is required than with high humidity and slower motion. Thus 70 deg. F. or more may be necessary to maintain comfort under certain conditions.

And again:

The effects of a humidity which is too low may be partly overcome by maintaining a little higher temperature; the effects of a humidity which is too high, a condition only found in warm weather, can be overcome by air motion.

Air has two principal functions: a chemical and a physical. It aerates the blood and it absorbs the body heat. For the performance of its chemical function it must contain a sufficient amount of oxygen and be free from poisonous gases; for the performance of its physical function it must have the proper temperature, humidity and motion to enable it to carry away the surplus body heat.

From his article, "How I Run My School," Prof. Wm. E. Watt, a principal of Graham Public School, Chicago, is copied:

Now what is the result of my pupils studying in this right atmosphere? Their skins are not parched; their eyes, ears and other sense organs are not dried out; their breathing apparatuses are not filled with disease; and their bodies are not weakened so that the least effort wearies them. They are free from those habitual headaches which they formerly suffered daily. They are able to think. They have a natural desire for knowledge. They can remember what they have read. They are enabled to think naturally. Now that is not theory—I am writing from what I have actually tried.

W. A. Evans, M.D., former health commissioner of Chicago, Ill., before the American Medical Association, may be quoted:

What is the remedy proposed?

1. Reduce the temperature of the rooms to a maximum of 68 deg. This temperature is more bracing. In such a temperature the exhaled air, being hot and moist, will rise right out of the breathing zone and be supplied by purer air.

2. Raise the relative humidity to 60 per cent. to 70 per cent. No possible objection can be raised to this except that it costs money to evaporate water and the windows will frost when the outside temperature gets to 20 deg. F. and below.

If the relative humidity is raised to 60 per cent. the pupils will be comfortable with a temperature of 68 deg. F.

Some of the frosting of the windows can be prevented by putting a radiator under each window.

But what harm does frosting do, anyway? Its harm is negligible as compared with the harm of over-dry air. It keeps out but little light, and under certain conditions of sunlight will give a mellower, softer light than the unobstructed pane.

And again in his paper presented here last year, entitled "Standards of Ventilation":

There should be humidity standards. Air which is too wet or too dry is unhealthy and uncomfortable. If it is too dry it desiccates mucous membranes; hence it determines infections. If it is too moist its conductivity is too high and

it determines infections. To hold the humidity fairly uniform permits of comfort under wider ranges of temperature. It permits of more air currents.
Suggested standard: 60 per cent. to 80 per cent. relative humidity, or 10 deg. to 20 deg. F. maximum difference between inside and outside humidity.

Mr. D. D. Kimball in American Architect, says:

Humidification has been referred to as one of the essentials of good ventilation. Relative humidity and temperature are most intimately associated. It is true that a temperature of 60 deg. or 65 deg. F. with a relative humidity of 50 or 60 per cent. is more comfortable and healthful than a temperature of 70 or 75 deg. with a relative humidity of 20 per cent., the latter condition being frequently observed in our homes, schools and hospitals during the winter.

The German engineer, Ludwig Deitz, in his treatise in Heating and Ventilating, says:

For hygienic reasons the humidity should be kept between the limits of 30 per cent. and 60 per cent.

For picture galleries he commends a relative humidity of 50 per cent. to 75 per cent. Again he says:

It seems to be proven that a too dry atmosphere is to be preferred to a too humid one. With rest, mixed food, normal temperature, and still air, 40 per cent. to 60 per cent., and at high temperatures, 30 per cent. to 40 per cent. seems to be most beneficial.

From a report of investigations made by Dr. T. A. Starkey, and Dr. H. T. Barnes of McGill University, Montreal, to determine the effect of successively dry atmosphere in human organisms, given in the Transactions of the Royal Society of Canada, has been taken the following:

The action of a dry atmosphere affects primarily the mucous membranes lining the respiratory tract, chiefly that of the nose, the throat and the bronchial tubes. It is a peculiar mechanical irritation resulting in a condition of congestion of mucous membranes before mentioned. If this irritation be continued for any length of time, the swollen membranes with difficulty regain their normal state. We have thus all the conditions favorable for chronic catarrh, and this chronic condition established, we get all the typical symptoms of nasal-pharyngeal catarrh, spreading often to Eustachian tubes communicating with the little ear.
When considering the effect of an irritation due to dry air on a mucous membrane already irritated or congested by some disease, e. g., tuberculosis, bronchitis, pneumonia, etc., none can deny for a moment the deleterious results that necessarily follow such added irritation.

Or with normal lungs and health, the mucous membrane lining gets irritated, and this condition is favorable for grafting of some disease—most of all tuberculosis.

Mr. Willis H. Carrier of Buffalo, N. Y., writes:

From personal observation covering a large number of installations where humidifying apparatus has been installed and tested, I find that a temperature of from 67 to 68 deg. with a relative humidity of approximately 60 per cent. is the most agreeable and invigorating atmospheric condition for sedentary work. However, I would place this as the extreme humidity desirable in an artificially heated dwelling.
It is undeniable that good ventilation and high humidity are both expensive so that the question from an engineering standpoint is not so much "What is the best possible condition of humidity and ventilation?" as "What is the minimum amount of ventilation and humidity consistent with good results?" I would place the minimum per cent. of humidity allowable in heated buildings for personal comfort at 38 per cent., which would correspond to 3 grains of water vapor per cubic foot at the room temperature of 70 deg. and the dew point or saturation temperature of 42 deg. Moreover, we find some of the most delightful so-called dry climates in which these conditions normally obtain.

Prof. S. Homer Woodbridge, of Massachusetts Institute of Technology, takes the stand that more air must be supplied to a building for proper ventilation where humidifying is done, than where dry air is furnished, the ratio being as 50 to 35. The reason stated being due to the more rapid morbification of the organic matter in a humid atmosphere, and he further draws the conclusion that for this reason humidifying is undesirable.

Ventilating plants are not intended for use only in extremely cold weather, but usually every one (excepting the operating engineer) intends and desires their use at all times, when heating is required; that is, when windows cannot be opened wide. Therefore the operation of the ventilating apparatus is required in what might be called moderate weather of 45 deg. to 55 deg. With these temperatures it quite often occurs that the moisture is sufficient to maintain a moderate relative humidity (40 per cent. to 50 per cent.) in the building. Then at such times, if more air is required, it would seem that the size of our ventilating equipment must be designed of sufficient capacity to properly ventilate with this moderate humidity condition.

Would not therefore a better plan be to provide for sufficient ventilation with moderate humidity of say 35 per cent. to 40 per cent. and also maintain that relative humidity as a minimum condition and prevent the very dry conditions which would otherwise be produced in very cold weather? The conclusion drawn of the benefits of a dry atmosphere, however, is greatly weakened in a later paragraph of the same paper which reads as follows:

> On the other hand, it is unquestionably true that some persons are so physically constituted that considerable moisture is essential to the proper functions of certain organs, and that dryness more or less seriously affects and irritates the delicate mucous membranes of mouth, eyes, nose, throat, lungs and also the action of the skin of some. Where such conditions exist, they must be regarded as of first importance, and moisture of sufficient quantity must be furnished for such cases.

The author's own observations are that a large percentage of our homes are overheated; viz., are heated above 70 deg. F. a large part of the time (he believes fully one half the time), and that this overheating is often necessary for the comfort of the occupants and of the author himself. He has often taken readings of the relative humidity in his own home, and has noticed with a humidity of less than 30 per cent. that 70 deg. F.

is not comfortable for any of the members of his family. With higher humidities, however, 65 deg. to 70 deg. is very comfortable.

He has found relative humidities indoors in offices here in New York, ranging from 8 per cent. to 20 per cent. on a great many occasions, and in his own home, when the humidifier was shut off, as low as 11 per cent. with 65 deg. temperature. The author's testimony is that he is much more comfortable with a moderate humidity than a low one, unless he resorts to overheating.

It must be borne in mind that the ordinary conception of average outdoor humidity as based upon the observations of the Weather Bureau is erroneous as these observations are made only at 8 o'clock in the morning and 8 o'clock in the night, at which times the relative humidity is often very high. The average range of humidity throughout the working day would probably be found to lie between 35 and 65 per cent. on any clear day.

The one phase of this question of the effect of humidity on which most people seem to agree is the very one that the author's own experience leads him to quite different opinions. He refers to the effect of high humidities in warm weather. Before giving his views scientific authorities who have studied this question with more or less thoroughness may be quoted:

Quoting Prof. Winslow again:

At a temperature above 70 deg. the body must rely largely on evaporation of the water of perspiration for maintaining its normal temperature.

Prof. Theodore Hough says:

So long as this perspiration can evaporate readily, there is little difficulty in keeping output equal to production. When, however, owing to high humidity evaporation is lessened, blood is rushed in larger quantities to the skin at the expense of the flow to other organs; the temperature of the skin is raised and so heat transfer by radiation, conduction and convection is facilitated. The normal temperature of the body is approximately maintained; but it is at the expense of the working efficiency of other organs and especially that of the brain.

I would, therefore, conclude that the most important, if not the sole cause of the acute effects of poor ventilation, is the combination of high temperature and high humidity which then obtains. It is neither of these acting alone but the two working together which introduce into the system the unfavorable circulatory conditions we have described.

In a report of the Committee on Ventilation of Cars appears:

At 80 deg. F., with moderate humidity, or at 70 to 73.5 F. with high humidity, practically all persons began to show evidence of depression, headache, dizziness or a tendency to nausea. It was shown that these symptoms began to develop in healthy people when the surface temperature on the forehead reaches 93 to 95 deg. F., with the moisture of the skin increased by 20 or 30 per cent. Under these conditions the normal dissipation of body heat is interfered with, and it is then that symptoms appear which are in every way similar to those developed in overfilled and "stuffy" rooms.

The next five extracts are from the report of the testimony taken before the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds in England:

A paper on the influence of high air temperatures was published by Dr. J. S. Haldane (M.D., F.R.S., of Oxford University) in the "Journal of Hygiene," v. 4 (October, 1905). The details relating to his experiments are very fully set forth and may be summarized by the following quotation:—

> It is clear that in still and warm air what matters to the persons present is neither the temperature of the air, not its relative saturation, nor the absolute percentage of aqueous vapor present, but the temperature shown by the wet bulb thermometer. If this exceeds a certain point (about 78 deg. F. or 25.5 C.) continuous hard work becomes impracticable; and beyond about 88 deg. F. or 31 deg. C. it becomes impracticable for ordinary persons even to stay for long periods in such air, although practice may increase to some extent the limit which can be tolerated. In moving air, on the other hand, the limit was extended upwards by several degrees.

The statement here quoted was corroborated by Dr. Haldane when giving evidence before the Committee. Dr. Haldane, while admitting that the relative humidity was an important element when considering the deposition of moisture from the air and the possible chilling effect on leaving the sheds, was emphatic in pointing out that relative humidity is not what determines the effect on the human system. He states:—

> I should propose that 75 deg. wet bulb be taken as a maximum; that is to say, that the schedule (for weave sheds) should stop at 75 deg. wet bulb.

Again he says:

With a view to my evidence before this Committee, I have recently made some experiments on the effects of moderate heat and moisture on persons wearing their ordinary indoor clothing. I found that in fairly still air and with a wet bulb temperature exceeding about 70 deg., and with muscular exertion, comparable to that needed in managing looms, the skin and clothes became damp and uncomfortable from perspiration when ordinary indoor clothing was worn. There was little or no discomfort if the wet bulb was below 70 deg. The effect seemed to be the same whether the temperature by the dry bulb thermometer rose or fell, provided the wet bulb temperature was the same, whereas any rise in the wet bulb temperature above 70 deg. very rapidly increased the effect. With lighter clothing, such as would be worn indoors in summer, a wet bulb temperature of 3 or 4 degrees higher was needed to produce the same effect; and for this reason, and in view of the difficulty of controlling rise of temperature in weaving sheds in summer, I think that the higher wet bulb temperature should be allowable in summer, although a wet bulb temperature below 70 deg. would at all times be preferable.

It is chiefly because of the discomfort, dirt, and untidiness caused by constant perspiration, that I think it desirable to keep the wet bulb temperature below 70 deg.

S. Pembrey, M.D., of Guy's Hospital, London, in testifying, said:

The results show definitely that a man is much less efficient in a warm moist atmosphere. Temperature indicated by the wet bulb thermometer and wind are the most important atmospheric conditions. The effects were studied by determinations of the internal and surface temperatures of the body, the pule, blood pressure, respiration, loss of moisture from the body, and retention of moisture in the clothes. A man can do far more work with less fatigue at a low wet bulb temperature than at a high one.

Efficient work can not be performed, unless the temperature of the body is prevented from rising above a certain optimum. The temperature depends upon the production and loss of heat; work increases the production, and the passage of more blood through the blood vessels of the skin and the evaporation of sweat increase the loss. A warm, moist atmosphere hinders the loss and taxes the power of accommodation of the worker.

And again in his report on the "Physiological Condition of Weavers Working in Warm, Humid Atmospheres," a synopsis may be stated as follows:

At your request a further investigation has been carried out to ascertain more fully the physiological conditions of weavers at work. This investigation was deemed necessary because, although the observations, already referred to, show a

rise of mouth temperature associated with a rise of the wet bulb temperature, yet the temperatures recorded do not exceed those which occur when exercise is taken by healthy adults under reasonable conditions of work.

The important thing is to keep the wet bulb temperature low, and to prevent the air from becoming stagnant and uniform in temperature.

A. E. Boycott, M.A., M.D., fellow of Brasenose College, Oxford, and lecturer on pathology in Guy's Hospital, before this same committee, said:

If hot air is at the same time moist, much more serious effects may be produced. These effects are directly dependent on the absolute reading of the wet bulb thermometer. . . . At rest and stripped I found my body temperature rose rapidly if the wet bulb exceeded 88 deg.-90 deg. F. with a dry bulb of about 100 deg., though no rise occurred with a dry bulb of 110 deg. and a wet bulb of less than 85 deg. I have on many occasions spent periods of about an hour in doing ordinary laboratory work in air with the dry bulb at 95 deg. and the wet bulb at about 65 deg. without any material discomfort. If, however, the wet bulb rises to 88 deg.-90 deg., one's body temperature soon begins to go up, even when completely at rest, and one becomes exceedingly uncomfortable and on occasions feels very ill.

Again he said:

From these considerations, therefore, I am of opinion that operatives should not be called upon to work with a wet bulb of above 75 deg. F., and that it would be desirable, though perhaps not always practicable, that the upper limit for active work should be 70 deg. F.

Leonard Hill, M.B., F.R.S., lecturer in physiology, London Hospital, Medical College, testified:

The heat losing mechanisms of the body are adjustable to varying conditions within wide limits, so that diminished loss by evaporation is compensated for by increased loss by conduction and radiation.

Also, before the (British) Institute of Heating and Ventilating Engineers, he explained that for the purpose of determining his experiments he constructed a chamber of 3 cubic meters' capacity (105 cu. ft.), in the interior of which was a fan. Eight of his students entered this chamber and were confined there for thirty minutes, not under the most comfortable conditions, it was true, for the wet bulb thermometer rose to about 80 deg. F., the air was depleted of its oxygen, and the CO_2 percentage rose. By putting the fan into operation, however, the discomfort of the imprisoned students was lessened, the stale air did not affect their breathing and the wet bulb temperature was lowered.

The general conclusion of the testimony of Mr. John Cadman, D.Sc., professor of mining at Birmingham University, late H.M. Inspector of Mines, may be briefly stated as follows:

72 deg. Wet Bulb.—Inconvenience is experienced, unless heavy clothing is removed and light clothing worn.

78 deg. Wet Bulb.—Little inconvenience is felt if considerable bare-body surface is exposed. Hard work is much facilitated if a perceptible current is passing over the body.

82 deg. Wet Bulb.—If clothes be removed, and maximum body surface exposed, work can be done providing current of air is available.

85 deg. Wet Bulb.—Body temperature becomes affected, and only light work is possible.

95 deg. Wet Bulb.—Work becomes impossible.

TABLE ILLUSTRATING DR. CADMAN'S EVIDENCE IN UNDERGROUND WORKINGS OF MINES. TEMPERATURES OBSERVED IN TRINIDAD:—

TEMPERATURE, DEGREES F.		
Dry Bulb.	*Wet Bulb.*	
83	73	Working in office at rest, no discomfort.
84	76	Sitting in shade after walking in sun with temperature 112 deg. dry bulb, perspired freely, but felt no discomfort.
86	78	Natives working excavating asphalt at this temperature. Very little work was being done, but little inconvenience appeared to be experienced. The temperature at this work occasionally rose to 120 deg. dry, 80 deg. wet. Little difference in effect upon the workers was noted. . . .
85	80	Very depressed, no inclination to exert myself. Everyone seemed very disinclined to work.
85	81	No breeze, very uncomfortable; unable to concentrate thoughts on any subject.
87	83	Very depressed, unable to exert myself to any degree. On turning on electric fan and sitting in breeze felt very refreshed and able to do a little writing.

These observations are taken from my notebook containing a considerable number of observations. In all the cases noted my body temperature was normal. At the time these notes were recorded I had been in the colony of Trinidad two years, and was fully acclimatised.

Rubner, the most eminent authority in Germany on questions of body heat, says that an untrained man can bear in comfort a temperature of 75 deg. Fahr. and 80 per cent. humidity (wet bulb about 70 deg. Fahr.), only when he is quiet. At 73.4 deg. Fahr. and 6 per cent. humidity he found a resting man lost by evaporation 75 g. of water per hour, and at 84 per cent. humidity (wet bulb 70 deg. F.) only 19 g. These figures show how three-quarters of the heat loss must be maintained by conduction and radiation, when the wet bulb reaches 70 deg F.

Dr. Langlois, before the International Congress of Industrial Diseases, gave some very interesting facts relative to the effect on mine workers of humidity, temperature and air circulation. According to investigations made by Dr. Langlois he found at Ronchamps at a depth of about 3,280 ft., with the humidity such that the dry bulb showed 36.5 deg. C. (98 deg. F.) and the wet bulb 24.8 deg. C. (77 deg. F.) that work could be carried on, but that, when the humidity became greater even with a lower temperature, work became difficult. He found that with temperatures above 25 deg. (77 deg. F.) on the wet bulb, the ventilation has a marked effect on the workmen's physical condition and capacity for work, and if the air was stagnant, an appreciable illness is experienced, which passes off at once when the ventilating current reaches a velocity of 3.3 ft. per second. In still air at a temperature of 30 deg. C. (86 deg. F.) (wet

bulb) marked illness is felt, but conditions become supportable when the velocity of the ventilating current reaches 6.6 ft. per second.

Most of these references cited were made by Europeans who do not as a rule heat their houses to the temperatures common in this country, and whose summer weather is milder. This is especially true of England.

The author had occasion personally to investigate the records of five meteorological offices in England this past autumn, and he was particularly struck with several facts:

1. Their climate is so very much more uniform than ours. I do not mean only that they do not have the extremes that we do, but that their daily and weekly variations are nothing like ours; so they are used to this uniformity and any great variation has an increased effect.

2. In the Lancashire District, which is considered to be the most humid part of England, the highest wet bulb temperature I was able to find on record was 71.6 deg., and this was exceptionally high, while last summer, which was hotter than the average, the maximum wet bulb was 70 deg. F. Compare this with our wet bulb temperatures here in New York last July, of 77 deg. and 78 deg.

3. That while the relative humidity of England is higher than America, still the absolute weight of moisture in the air in summer is much less, due to the lower summer temperature.

There is a difference in the temperature which is comfortable for the average Englishman and that which best suits the average American of at least 10 deg. So in considering the statements made by those residing in England, bear in mind that the temperatures would probably be several degrees higher, which would produce the same effect upon persons used to our climate.

Now the author cannot agree with Drs. Haldane, Pembrey and Boycott nor Prof. Cadman, that the wet bulb temperature is the all-important thing that affects our comfort. Why?

Because of tests the author has made on installations which were designed to do cooling of buildings by evaporation. In these plants, air taken from outside is passed through a humidifier so constructed that the air is saturated without heating the spray water. In the evaporation of water under these conditions the latent heat required is procured by the cooling of the air.

Saturation is reached at the wet bulb temperature of the entering air, and in summer this wet bulb temperature on hot days in this climate, will be found to be from 12 deg. to 20 deg. lower than the temperature shown by the dry bulb thermometer.

This saturated air is blown into the buildings in sufficient quantities to absorb the heat of transmission from the outside

from the people and other internal sources and thus cool the building. When this hot air is saturated, of course moisture is added, the humidity is increased, and when it enters the building, taking up the heat therefrom, both the dry and wet bulb temperatures are raised above the saturated temperature. Then necessarily the wet bulb temperature in the building is higher than that outside, and according to the ideas of Dr. Haldane, it should be more comfortable out of doors than inside.

One June 22, 1910, the thermometer outside the author's office window reached 93 deg. in the shade, with a wet bulb temperature of 78 deg., and 59 per cent. relative humidity with 9.26 grains per cubic foot. This room, which had very large windows, was on the southwest corner of the building and was located immediately under the roof, so it was receiving the full benefit of the sun. By introducing fresh saturated air the temperature was dropped from 90 deg. to 83 deg., and the humidity increased to 84 per cent., with a wet bulb temperature of 79 deg.

We took no body temperature readings, but ran the test and those on succeeding days for the purpose of observing the effect upon bodily comfort. The results for the three occupants were vastly more pleasant than those produced naturally and callers coming in from the other parts of the building or from the streets, invariably were struck with the much more pleasant atmosphere, and remarked upon it without any questioning on our part. In these tests the air change was rather high, about one change every two minutes. The distribution was such, however, that no draughts were felt.

A chemist and manager of a large plant for whom we have installed two plants for cooling by evaporation, writes:

Experience within our institution has shown that ideal working conditions for male and female help are temperatures from 70 to 74 degrees, and humidity percentages approximating between 72 and 76 per cent. This has reference to the comfort of the help exclusively.

The introduction of moist, cool air into a building during hot weather for the purpose of lowering its temperature, certainly has the immediate consequence of furthering the working man's comfort as against higher temperature and dryness of the air.

I have never observed a chilling effect in summer time when we tried to reduce the inside temperature from 10 to 12 degrees below that of the outside, but I have noticed that in order to force a maximum difference of temperature between outside and inside figures, that the velocity of air circulation has to be increased to an extent which is disagreeable to the help engaged in work at a given spot.

I enclose herewith a slip showing conditions on a few of the hottest days we had this year in Hazleton.

In reply to your particular query as to whether or not our operatives considered conditions obtained as more favorable than if no cooling apparatus had been installed, I can state positively that such is proven the fact that some portions of our plant are not provided with adequate cooling and moistening apparatus with the result that the help request constantly to be transferred to the other parts where improvements are installed and conditions ideal.

The following is the table referred to above:

Date.	Outside Temp. Dry B.	Outside Temp. Wet B.	Rel. H. Per cent.	Inside Temp. Dry B.	Inside Temp. Wet B.	Rel. Humidity. Per cent.
July 20	93	74	40	82	76	76
" 24	95	76	41	84	78	77
Aug. 3	91	69	32	78	72	75
" 11	94	74	38	82	76	76
" 15	91	73	41	80	75	79
" 28	89	72	44	78	74	83
Average	90.5	73	39.3	80.75	76.83	77.66

Another engineer, a man who has done a great deal of testing laboratory work, in which the conditions were very exacting, and required the control of temperature and humidity, writes as follows:

Referring to the matter of the more pleasant working condition of temperature and humidity, we can state that under the conditions shown by the readings below, the inside condition with a lower temperature, but higher humidity is more pleasant than the outside condition with higher temperature and lower humidity.

The readings following are actual observations of dry and wet bulb for two consecutive days last summer.

Outside.		*Inside.*	
Dry	90	Dry	85
Wet	80	Wet	79
Per Cent. of Hum	65	Per Cent. of Hum	77
Dry	90	Dry	82½
Wet	77	Wet	78
Per Cent. of Hum	55	Per Cent. of Hum	82

These gentlemen are not expressing opinions, but are giving testimony of what they know to be true from actual observations of the effect upon themselves and others.

With the same difference between the dry and wet bulb temperatures, evaporation is just as rapid at the low as at the high temperatures, provided an equal amount of moisture is being presented to the skin surface, and the supply is equal to the evaporation. This law of the relation of the evaporation to the wet bulb temperature has been well established in investigations of the drying of materials.

It is generally considered by those who have studied the subject that an average person with moderate exercise and normal temperature gives off about 500 B.t.u. per hour, of which approximately 50 per cent. is radiation and convection and 50 per cent. is evaporation.

When the atmospheric temperature reaches the body temperature then all the heat must be dissipated by evaporation. Taking, for example, an average of the temperatures given above. The average of the outside dry bulb temperature was 90.5 deg. F., giving a difference between the body temperature of 98 deg. and that of the outside of 7.5 deg.

Inside the average of the dry bulb temperature was 80.75 deg., giving a difference between the room and the body temperatures of 98 — 70.75 deg. = 17.25 deg. The relative loss of heat by radiation and convection therefore was 17.25 ÷ 7.5 = 230 per cent. of that which would take place outside with the same air motion.

The average of the outside wet bulb temperature was 73 deg. giving an average wet bulb temperature depression of 90.5 deg. — 73 deg. = 17.5 deg.

The average of the inside wet bulb temperature is 76.83 deg., giving an average depression of 80.75 — 76.83 = (practically) 4 deg. The relative loss of heat by evaporation therefore is 4 ÷ 17.5 = 23 per cent.

Here bear in mind the wet bulb temperature was almost 4 deg. higher inside than outside, and yet it is certain the conditions were more comfortable in the building. As practically all the heat must be lost by evaporation with the higher temperature, perspiration is greatly increased in order to provide the required evaporation. The flow of perspiration to the surface of the skin is dependent upon the heat generated in the body and the pores of our skin, not unlike every other organ, rebels at being overworked. This excessive evaporation is very uncomfortable, even though all the heat may be dissipated. By increasing convection and radiation the perspiration is reduced and the losses are more uniformly distributed.

It is not to be wondered at that providing conditions which distribute the heat losses more uniformly and nearer the normal ratio is found to be more desirable. There can be no question that with a stationary high temperature a moderately low humidity is more comfortable than a high humidity. On the other hand, the author is convinced that under certain conditions low humidities and high temperatures are not so comfortable as high humidities and lower temperatures.

Cooling by evaporation has perhaps its limitations like almost everything else, and the author is not prepared to say where this limit lies, but from the figures quoted, it will be seen that some of the humidities are very high.

One thing that undoubtedly has considerable to do with our comfort is the "comparative condition." We can be quite comfortable in summer with conditions that would be uncomfort-

able in winter, or vice versa. We become accustomed to high temperatures or low temperatures and they cease to be disagreeable. A case has been given where 83 deg. and 84 per cent. humidity was more comfortable than the outside temperature of 93 deg. and 59 per cent. humidity. The conditions were only comparatively comfortable, very much better than the natural outside atmosphere, but no one would desire such conditions except as an alternative for something worse.

Prof. Woodbridge in "Air and Its Relation to Vital Energy," says:

> Because water vapor has a higher specific heat than air, a humid air at a lower temperature than the body extracts heat from the body more rapidly than does dry air at the same temperature.

And an extract from Prof. C-E. A. Winslow's paper, reads:

> If the temperature be below 68 deg., . . . an excess of moisture may exert deleterious effects of a precisely opposite kind. Under these conditions the body tends to cool too rapidly rather than too slowly, and the secretion of perspiration ceases. The moisture in the air no longer has any heating effect, but, on the other hand, its presence raises the specific heat of the atmosphere, increases the amount of heat a given volume of air will take up from the body by conduction or convection, and thus directly exerts a cooling influence on the body. We have thus the somewhat paradoxical condition that excessive atmospheric moisture increases the bad effect of either heat or cold.

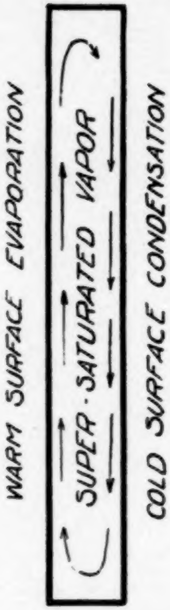
Dr. Henry Mitchell Smith states:

> But aqueous vapor is one of the best gaseous absorbents of heat; therefore the loss of the body heat by convection is very great if the absolute humidity is high and the air is in motion. This accounts in the main for the greater feeling of cold on these raw days.

The author is not prepared to accept these statements, except in theory only, as the difference in the specific heats is too small to have any practical effect. The relative heat conductivity of gases is the product of specific heat and density. One cubic foot of air at 50 deg. weighs 0.078 lb., and at 50 deg. with 100 per cent. humidity the weight of moisture would be 7 gr. which equals 0.00057 lb. Then the conductivity of heat by the air is $0.078 \times 0.2378 = .01855$, while that for the water vapor in the air is $0.00057 \times 0.48 = 0.0002736$, which is only about 1.5 per cent. of that of the air, so that it does not seem to me that this small increase could be noticed.

On the other hand, we all know how very chilly we can be with a temperature of 40 to 50 deg. and a high humidity, while the same temperature and a low humidity may feel quite delightful. Rubner says an increase in the relative humidity of 12½ per cent. has the same effect upon the delivery of heat as the lowering of temperature of 1.8 deg. F.

Mr. Carrier also writes:



> **As heat is conducted from the body both by convection and evaporation, the relative proportion thus transferred is dependent—**
>
> **1. Upon the amount of energy generated within the body itself.**
>
> **2. Upon the difference between the atmospheric temperature and the body temperatures.**
>
> **3. Upon the amount and texture of the clothes.**
>
> **In general, the smallest proportion of heat will be liberated by evaporation when the difference between the atmospheric temperature and the body temperature is greatest, when the bodily heat is the least as in sedentary work, and when comparatively light clothing is worn. Under opposite conditions, the reverse is true and the dissipation by evaporation reaches a maximum when the body is completely covered with perspiration.**
>
> **From these considerations it is evident that the body may be considered as a *partially* moist surface and that the relative effect of the wet bulb and the dry bulb temperatures upon the sensation of heat and cold depends entirely upon the degree of bodily moisture. This in turn is dependent upon the several conditions above mentioned.**
>
> **It is quite conceivable that air with a lower dry bulb temperature and a higher wet bulb temperature might seem appreciably cooler to one person sedentarily engaged, while in another person actively engaged or differently clothed, it would seem *warmer* than the atmospheric of higher dry bulb temperature and lower wet bulb temperature. It is certain where the dry bulb temperature is at bodily temperature, the sensation of heat is entirely dependent upon the wet bulb tmperature. *In all other cases, however, it is dependent in varying degrees upon both the wet bulb temperature and the dry bulb temperature.***
>
> **Below 50 or 60 deg., very moist air produces a much more marked sensation of cold than drier air having a lower wet bulb temperature. The reasons for this are apparently two-fold:—**
>
> **1. At the lower temperatures the bodily heat is largely taken care of by radiation. The surface of the body is less moist and therefore less affected by wet bulb temperature.**
>
> **2. In the process of convection of heat from the body through the clothing, a mixture of warm, moist air from the body with cold, moist atmospheric air produced a condition of super-saturation in the mixture causing a deposit of invisible moisture particles upon the fibre of the cloth. The presence of this super-saturation or free moisture in the clothing or even of a high degree of regain in the cloth itself sets up an independent process of convection through condensation and reëvaporation of the moisture in the clothing. This process if freely carried on would be immensely more affecting than the ordinary process of convection. In other words, damp clothing conducts heat more rapidly than dry clothing. An ideal diagram of the process is shown herewith.**
>
> **The reason for this action not taking place in dry cold air is that where this air is sufficiently dry super-saturation will not occur in the mixture with the warm air from the surface of the body.**

Mr. Konrad Meier in his paper entitled "Hygiene in Heating," says, that "moistening is rarely needed," and——

> **Proof has been furnished that the stuffiness of air in heated rooms is caused by the decomposition of dust in contact with radiating surfaces at temperatures of 160 deg. F. and higher.**

Also:

> **This process is not one of combustion, generating carbonic acid, but a sort of dry distillation or singeing of the organic matter, which produces small quantities of the highly injurious ammonia, also traces of carbon monoxide and other gases. The presence of the former gas is explained by the quantities of animal excreta, one of the principal ingredients of ordinary street-to-house dust. It shows the little appreciated fact that dust while comparatively harmless on furniture, will become objectionable when allowed to settle and decompose on radiators.**

This statement overlooks the fact that the amount of dust floating in the air is dependent upon the relative humidity. The

Bureau of Mines in their experiments at the Pittsburg Station, used a horizontal cylinder, 6 ft. in diameter by 100 ft. long, provided with shelves on which coal dust was sprinkled and then subjected to different humidities. By firing a cannon in one end of the cylinder terrific explosions would be produced with low humidities while with a humidity of 80 per cent. there would be no explosion. This fact was shown to be not the result of any dampening of the dust in the cylinder, but due to the fact that with the higher humidity there was less dust floating in the air to ignite and spread the flame.

The same is true of dust in buildings. Maintaining a moderate humidity prevents the drying out of the dust, thus rendering it less subject to draughts and other disturbances which would tend to scatter it over surrounding objects, and having less dust finds its way to the radiator to be distilled.

Objection is often raised to condensation on windows where humidifying is done. Windows are usually provided for the purpose of admitting light, and to allow a view of the surroundings from the inside. Frosting on the windows obstructs very little light, while it does interfere with vision, but this is usually not of much importance. When condensation occurs in sufficiently large quantities to run down on the window sill, it is objectionable and the best cure is to provide double windows, as a humidity of 35 per cent. to 40 per cent. will condense and flow on a window which the wind strikes on a cold day, viz., 10 deg. above zero F. or below.

The cost of humidifying, while not being by any means a minus quantity, as has been often stated, still can not be considered as prohibitory or excessive. The amount of power for running the circulating pumps for the spray water is small; the greatest expense being the heat necessary to procure the required evaporation in winter. One boiler horse power is required for each 3,500 cu. ft. of air per minute, to which is added one grain of moisture per cu. ft.

In a building with 21,000 cu. ft. of air supplied per minute, where it was desired to carry a relative humidity of 40 per cent. with 68 deg. temperature, the amount of moisture to be conveyed per cu. ft. would be 3 grains. So it might be expected on a zero day to be necessary to have to add to the incoming air two and three-quarter grains per cubic foot.

$21{,}000 \times 2.75 \div 3{,}500 = 16.5$ boiler horse power of steam required.

Quite often in taking readings of relative humidity in winter it will be found that the absolute humidity indoors is greater than that of the outside atmosphere, where the air change is small or intermittent. This is due to the hygroscopic properties of the walls, furniture and furnishings, which absorb moisture when the relative humidity is high, and give it off again when it is low.

In those buildings provided with mechanical ventilation which is kept in constant use, the rapid and continuous circulation of the air soon takes up the moisture given up in this manner. So, generally speaking, the buildings greatest in need of humidifying apparatus, are those provided with the better types of ventilating plants.

The scope and length of this paper does not permit of a discussion of the best means for regulating humidity, excepting that it will be found that for those buildings provided with ventilating equipments, the most satisfactory results will be obtained by the use of air washers provided with thermostatic means for controlling the temperature of saturation. For residences, offices and buildings not mechanically ventilated, special self-contained portable humidifiers have lately been put on the market, from which exceedingly satisfactory results can be obtained.

The author has quoted only a few of those who have made a study of this subject, but he has endeavored to select those who would give as many different ideas and theories as possible.

CONCLUSIONS

His conclusions are:

1. That there is but little evidence to indicate with any degree of exactness the most desirable humidity for health and comfort, excepting that extremes should be avoided, which seems to be so well established, and the limits would seem to be between 30 per cent. and 80 per cent.

2. That low humidities are uncomfortable unless accompanied by high temperatures.

3. Low humidities are detrimental to health.

a. By affecting the membranes of the mouth, nose, throat, lungs, eyes, etc., and thereby reducing the resistance to infection by the bacteria of such diseases as tuberculosis, bronchitis, pneumonia, and catarrh.
b. By the increase in the amount of dust floating in the atmosphere carrying these and other injurious bacteria.
c. By irritation of nervous system through excessive dryness of the skin and excessive evaporation, thus producing nervous tension even in a healthy person.

4. Unless special provision has been made in the construction of the buildings, high humidity in cold weather will be objectionable on account of excessive condensation running from the windows over the woodwork and wall decoration.

5. In order to best satisfy these conditions in second, third and fourth, in cold weather the relative humidity should be maintained between 35 per cent and 45 per cent.

6. There is no evidence that observations have been made of the "comparative effect" by those who claim that low humidities accompanying high temperatures to be preferable to higher humidity and lower temperature.

7. There is evidence that cooling of buildings by evaporation can produce conditions in the building more comfortable in hot weather than the natural conditions, although the wet bulb temperature is increased.

8. That the determination within closer limits of the relative humidity and temperature best suited to the comfort and health of the greatest number of persons is of sufficient importance to require the study and investigations of physicians and scientists.

DISCUSSION.

Mr. Frank L. Busey: In connection with this paper I wish to call attention to the relation between the relative humidity in the room and the steaming of the windows. I have recently been conducting a series of experiments in an endeavor to obtain more definite information on this subject, the results of which are given in the accompanying table.

The room selected for the tests is an ideal one for the pur-

pose, approximately 45 ft. square by 9½ ft. high, exposed on the east, south and west sides. Two of these sides each have six windows, while the south side has seven, part of these being double, that is, fitted with storm windows. The room is warmed by means of a fan blast heater, the air being drawn through a Carrier air washer fitted with a humidity control.

The air is taken directly into the washer without first passing through a tempering coil, the different dew-point temperatures and relative humidities being obtained by varying the temperature of the spray water. This is accomplished by controlling the amount of steam admitted to the spray water. By this means the different humidities in the room were obtained, the only precaution required being that the temperature in the spray chamber be maintained above the freezing point, or approximately 35 deg. Due to this limitation the lowest humidity obtained in the room was about 29 or 30 per cent. The outdoor temperature ranged from 4 to 25 deg. above zero and the relative humidity in the room was varied from 29 to 64 per cent.

In the accompanying table the per cent. of the glass surface on each side of the room that is covered with moisture is given, moist meaning the glass is steamed over and wet indicating that considerable water has collected and sometimes running down the glass. In no case did the water run from the windows in sufficient quantity to be particularly objectionable. It will be noticed that where the windows were double but little trouble was experienced with moisture.

There is one small office connected with this same heating system where considerable trouble was experienced with water on the windows whenever the relative humidity went above 40 per cent. This is a corner room, exposed to the full force of the wind, and with a very frequent air change—perhaps once in 2 or 3 minutes.

The room in which the experiments were conducted is used for a drafting-room and nearly all of the men work in their shirt sleeves so that ordinarily a temperature of 71 or 72 deg. is required, the relative humidity varying from 35 to 40 per cent. The column headed room conditions is merely an approximate average based on the opinion of the men about the room. Any discrepancy in these items is probably due to the effect of the wind being stronger during some tests than others. It might

be of interest to state that before the humidity control apparatus was installed, humidity readings made in this room have shown as low as 8 per cent.

Based on the results of these experiments a number of conclusions may be drawn. The windows equipped with storm sash gave very little trouble from steaming, and then only with a relative humidity of 50 per cent. or greater, the room temperature being 71 deg. and outdoors about 10 deg. above zero. With a relative humidity of 51 per cent. and an outdoor temperature of 23 deg. above zero only a trace of moisture formed on them. The sides of the room exposed to the wind gave the most precipitation of moisture on the windows, the protected windows seldom having more than a coating of steam or moisture.

On a stormy afternoon with a strong wind and a rapidly falling outdoor temperature, ice began to form on the exposed windows when the relative humidity was raised above 40 per cent. As the humidity was raised above 64 per cent. even the double windows steamed entirely over, and due to the failure to reduce the room temperature sufficiently the room conditions became very uncomfortable.

In the room in question and for the purpose for which it is used a temperature of from 70 to 72 deg. with a relative humidity of from 35 to 40 per cent. gives very satisfactory conditions. With ordinary weather the moisture does not collect on the windows in sufficient quantities to become objectionable, but even with as low as 35 per cent. a strong cold wind will cause the exposed windows to partly steam over.

CCLXXVI.

CHEMICAL NOTES ON VENTILATION.

BY PERCY NORTON EVANS.*

What is the direct cause of the enervating and injurious effect of poor ventilation on the human system is still uncertain. The old theory that it is due to increased carbon dioxide and decreased oxygen in respired air seems quite inadequate in view of the smallness of the actual difference between ordinary poor air and fresh air; to be sure, the carbon dioxide may be increased many times, and the air not be poisonous, and experiments have shown that equal quantities added to air by purely chemical means have no such marked physiological effects; and the concentration of oxygen is altered to a scarcely appreciable extent in any case of ordinary poor ventilation.

It is held by some that definite toxic substances are exhaled in respiration, and that these rather than the alteration in the proportions of inorganic constituents of the air are responsible for the undesirable effects. Exhalations from the skin have also been considered of importance, and this hypothesis receives some measure of confirmation from the very noticeable difference in the intensity of the effect of a well-washed and a not-well-washed crowd in a poorly ventilated assembly room, the respiration products being the same in both cases presumably. Again, some claim that the excessive moisture is an important factor, but this seems an insufficient explanation, for the air of badly ventilated buildings in cold weather contains nothing like the amount of moisture present in fresh air in warm damp weather.

Whatever the cause or causes—and they may be many—of the evil effects of poor ventilation, it is surely true that anything that tends to carry away the air that has been exhaled or in contact with the person and replace it by fresh air, must be beneficial.

Elaborate provision is often made to insure by mechanical means this movement of air. As will be shown, something can

* Non-member; Department of Chemistry, Purdue University, Lafayette, Ind.

also be done by automatic physical means to bring about the same result, and where mechanical means are employed they should for economy and efficiency operate in such a direction as to assist rather than oppose the natural automatic movement.

It was formerly thought that foul air, that is, air that has been breathed, was more dense than fresh air, because part of the oxygen of the latter is replaced by carbon dioxide in the lungs, and carbon dioxide is denser than oxygen, and consequently that expired air tended to fall and foul air to accumulate at the floor of the room, so that for the best results the removal of air should be from near the floor. This reasoning overlooked the fact that oxygen is also replaced by water vapor in the lungs, and water vapor is lighter than oxygen; also that the expired air is at a higher temperature than the air of the room and on this account less dense. This error is no longer generally made in the discussion of the principles, although it often is in practice. As will be shown, expired air is actually lighter than fresh air under ordinary ventilation conditions, and therefore tends to rise and accumulate near the ceiling. This is assisted by the natural upward movement of air in a building warmer than its surroundings, as in a flue, and further by upward currents in the neighborhood of any body warmer than its immediate surroundings, such as a stove, a burning lamp or gas jet or electric light, or even the body of a person. That foul air tends to accumulate near the ceiling is evident to those occupying the gallery of a crowded auditorium.

An experiment to test this upward movement of respired air was made by the writer in a classroom about 27 x 30 ft. and 16 ft. high. The room temperature was 24 deg. C. (75 deg. F.), and the outdoor temperature 10 deg. C. (50 deg. F.); the moisture in the air of the room, as shown by a Mitthof hygrometer, was between 50 and 60 per cent of saturation. The windows and doors and a ventilator were closed during the period of the experiment, and the only source of artificial heat in the room was a vertical steam pipe, the radiator being shut off by the automatic thermostat.

The room was occupied by 26 adults for 50 minutes and was then unoccupied for 10 minutes immediately before the period of experiment, which also lasted 50 minutes, 36 adults being present, seated.

Carbon dioxide was determined in the air with a Lunge air tester, samples being taken alternately from within 6 in. of the ceiling and the floor through tubes and analyzed on a table near the center of the room. The analytical method consists in forcing the air through a standard solution of sodium carbonate colored pink with phenolphthalein, by squeezing a rubber bulb until the pink color disappears, the number of squeezes being counted, and ranging in this experiment from 8 to 5, fresh outdoor air requiring 48 squeezes with the apparatus used.

The results for the successive samples from near the ceiling were 14.5, 16.0, 18.0 and 21.0 parts of carbon dioxide in 10,000 parts of air by volume; near the floor the figure obtained was 14.5 in 3 successive samples. Moisture readings with the hygrometer showed an increase from 52 to 58 per cent. of saturation during the experiment near the ceiling and from 55 to 58 below the table —a greater increase near the ceiling. These results show that the respiration products, carbon dioxide and moisture, move upward under these conditions.

The influence of the *temperature* and *moistness* of the air of the room on the upward movement of expired air will be shown in what follows.

The temperature of the exhaled air is necessarily body temperature, 37 deg. C. (98.6 deg. F.); that of the surrounding air of the room can be controlled in an artificially heated building, and since the cold air is denser than warm air the lower the room temperature the greater will be the difference in density between it and the exhaled air, and the greater the tendency of the latter to rise and be automatically removed from the respiration level. Failure to take advantage of this principle probably accounts in part at least for the enervating and depressing effects of overheated rooms in our homes, schools, offices, public buildings, and, worst of all, our hotels. The usual temperature aimed at in this part of the country is well up in the seventies—a very mistaken form of luxury; it should be at least ten degrees lower, and sensible habits in clothing, especially on the part of fashionable women, would soon remove the apparent hardship. The accepted temperature for schoolrooms in England is said to be 58 deg. F., and the standard temperature of the room generally accepted in European scientific work is 15 or 15.5 deg. C. (59 or 60 deg. F.).

The moisture factor is similar to the temperature factor in its

effect and to a less degree in its control. The exhaled air is always saturated with moisture, the air of the room if at a lower temperature than out of doors is not saturated unless moisture is added to it after entering the building, and in frosty weather it is commonly not over one-fifth saturated. Since, as already stated, water vapor is lighter than air, and since it displaces an equal volume of air, the less moisture there is in the air of a room the greater will be the tendency of the expired air to rise. There may be other reasons against having very dry air in buildings, such as irritation of the nose and throat, though this objection is at present debatable and not in agreement with the generally recognized benefits of breathing fresh air even at low temperatures; also there may be injury to furniture and woodwork, but from our present standpoint the drier the room air the better. In harmony with this is the very noticeable depressing effect of a very moist atmosphere.

Let us now consider the numerical values concerned in these densities under ordinary conditions.

Accepting Halliburton's values for the composition of fresh air and expired air both in the dry condition:

Fresh air	Oxygen	20.96 per cent by volume
	Nitrogen	79.00 per cent by volume
	Carbon dioxide	0.04 per cent by volume
Expired air	Oxygen	16.12 per cent by volume
	Nitrogen	79.45 per cent by volume
	Carbon dioxide	4.43 per cent by volume

The densities, compared with hydrogen at the same temperature and pressure, are:

$$\text{Fresh Air: } \left(\frac{20.96}{100} \times \frac{16}{1}\right) + \left(\frac{79.00}{100} \times \frac{14}{1}\right) + \left(\frac{0.04}{100} \times \frac{22}{1}\right) = 14.42$$

$$\text{Expired Air: } \left(\frac{16.12}{100} \times \frac{16}{1}\right) + \left(\frac{79.45}{100} \times \frac{14}{1}\right) + \left(\frac{4.43}{100} \times \frac{22}{1}\right) = 14.68$$

Considering now the effect of moisture on the density of expired air, the tension of aqueous vapor, or vapor pressure of water, is 47 millimeters of mercury at 37 deg. C. (98.6 deg. F.), therefore any gas saturated with water vapor at this temperature consists of $\frac{47}{760} \times \frac{100}{1}$ or 6.2 per cent water vapor. and 100. — 6.2 or 93.8 per cent. by volume of all other constituents together. The composition of expired air saturated with moisture at body temperature is therefore

Oxygen	16.12 x .938 or	15.12 per cent by volume
Nitrogen	79.45 x .938 or	74.52 per cent by volume
Carbon dioxide	4.43 x .938 or	4.16 per cent by volume
Water vapor		6.20 per cent by volume

The density of this mixture compared with hydrogen at the same temperature and pressure, calculated as before, the density of water vapor being 9, is 14.33.

Comparing then the densities of dry fresh air and expired air saturated with moisture, both at 37 deg. C. (98.6 deg. F.), we find them to be 14.42 and 14.33, respectively, the addition of the moisture having a greater effect in decreasing the density than the replacement of part of the oxygen by carbon dioxide in increasing it, if the inspired air is dry.

Taking into account such differences in temperature as are likely to occur between the inspired and the expired air, we find that since the density of any gas or mixture of gases is proportional to the absolute temperature, a density of 14.42 for dry fresh air at 37 deg. C., or 310 absolute, becomes at 20 deg. C., or 293 absolute, $\frac{14.42}{1} \times \frac{310}{293}$ or 15.26, so that the relative densities of dry fresh air at 20 deg. C. (68 deg. F.) and ordinary exhaled air (at 37 deg. C.) are 15.26 and 14.42. The difference between these figures, which is favorable to the automatic removal of respiration products for the level of respiration, decreases with any increase in temperature of the fresh air. A density of 14.42 at 37 deg. C. becomes 14.33 at 39 deg. C., for $\frac{14.42}{14.33} \times \frac{310}{1}$ or 312 absolute, is 39 deg. C.; therefore dry fresh air would have at 39 deg. C. (102 deg. F.) the same density as ordinary expired air (saturated with moisture and at 37 deg. C.), and at 39 deg. C. the automatic upward removal of respiration products due to difference in density ceases.

Having considered the case of perfectly dry air, let us take the other extreme of fresh air saturated with moisture at certain temperatures. The tension of aqueous vapor at 30 deg. and 35 deg. C. is respectively 32 and 42 millimeters of mercury, so by reasoning similar to that given the composition of fresh-air saturated with moisture at these temperatures is

At 30° C	
Oxygen	20.96 × 0.958 or 20.08 per cent by volume
Nitrogen	79.00 × 0.958 or 75.68 per cent by volume
Carbon dioxide	0.04 × 0.958 or 0.04 per cent by volume
Water vapor	4.20 per cent by volume
At 35° C	
Oxygen	20.96 × 0.945 or 19.81 per cent by volume
Nitrogen	79.00 × 0.945 or 74.65 per cent by volume
Carbon dioxide	0.04 × 0.945 or 0.04 per cent by volume
Water vapor	5.50 per cent by volume

The densities of these mixtures compared with hydrogen at the same temperature, say, 37 deg. C., are respectively 14.20 and 14.11, calculated as before, while ordinary exhaled air has the density 14.33 compared with the same standard (hydrogen at 37 deg. C.). Imagining these mixtures cooled down to 30 deg. and 35 deg. C., respectively, their densities become 14.53 and 14.20, calculated as before from the absolute temperatures. By interpolation we find that if densities 14.53 and 14.20 correspond to temperatures 30 deg. and 35 deg. C., 14.33 corresponds to approximately 33 deg. C.; therefore if fresh air is saturated with moisture it has at about 33 deg. C. the same density as ordinary exhaled air (saturated with moisture and at 37 deg. C.), therefore at 33 deg. C. (91 deg. F.), the useful upward movement of expired air ceases if the surrounding air is saturated with moisture.

A certain temperature between 33 deg. and 39 deg. C. corresponds to each degree of saturation with moisture.

SUMMARY.

It has been shown that under all ordinary conditions of ventilation the products of respiration move upward; that this upward movement, by which the harmful products are removed from the level of respiration, is assisted by a low room temperature, and by dryness of the air of the room; also, that the fresh air has the same density as expired air (saturated with moisture and at body temperature) at 33 deg. C. or 91 deg. F. if the fresh air is saturated with moisture, at 39 deg. C. or 102 deg. F., if perfectly dry, and at temperatures intermediate between these with different degrees of moistness.

CCLXXVII.

VENTILATION PROBLEMS

BY D. D. KIMBALL.

Ventilation as now practised by the heating and ventilating engineer is being very seriously criticised. Many new problems are being presented. We see references to "canned air" and air "roasted to 400 degrees," a manifest impossibility. Recently a physician of the highest standing in New York City, when asked his opinion of the value of ventilation, i. e., artificial ventilation, replied that there is no such thing as ventilation, stating that he had spent much time in making careful investigations and that his opinion was based upon clinical records in a large hospital practice. And this physician is not alone in a large company of doubters and questioners, including men whose experience and standing are such as to compel respect for their opinions. It is not, therefore, surprising to learn that some large hospital buildings have been built with no provision for artificial ventilation. That this represents the extreme swing of the pendulum from the work of the past and that the construction of buildings lacking such equipments portends a day of sadness and reckoning for these institutions, is readily believable.

There is a large group of men who have come to believe that too much emphasis has been placed upon the measuring of ventilation by either the volumetric or CO_2 basis and that such elements as temperature, relative humidity, dust, odors, etc., are of equal or relatively greater importance.

Also, we have with us the stand-pat element which goes on designing ventilating systems on the theory that given a sufficient volume of air supplied and removed the other problems may be neglected.

It is not the purpose of this paper to take to task the members of any of the above groups nor to question the immense value of past ventilation work, which, it is believed, has been thoroughly demonstrated. (See Ventilation and the Public Health,

by the author, pages 207 to 219 in the Public Health Movement issued by the American Society for the Adv. of Pol. and Soc. Science in March, 1911.)

It is unfortunate for the cause of ventilation that many ventilation systems have been produced which have given dissatisfaction, some because of the inexperience of their designers, others because of the interference of the owners or architects in the placing or design of the apparatus; often because of a penurious policy on the part of the owner or architect, which limits the appropriation and thus the capacity of the system; not infrequently because of the poor installation of a well-designed system, and very frequently because of a lack of skill in the operation of what would otherwise be a satisfactory system. These failures have been no small factor in the development of an army of critics and opponents to ventilation, there being quite a sufficient force to this opposition to warrant the serious attention of the members of this Society, to the end that the opponents and critics of ventilation may be fully answered, that the status of ventilation may be firmly established, and that the public may be generally informed.

It is beyond hope or reason that this may be accomplished by an arbitrary statement of our belief in the importance and accomplishments of ventilation. To reach the desired end involves a thorough presentation of the essentials and merits of ventilation.

This brings us face to face with the fact that it may well be doubted whether it is known to-day what are the essentials of ventilation; indeed, it may safely be stated that they are not known. Many are the supposed authorities and statements supporting our present ventilation standards, but actually little, almost no, basic or conclusive data or authorities are available which are acceptable to the biologist, physician or inquiring engineer. It is high time that this problem of promoting the health of the people by means of ventilation was given the benefit of a scientific and unquestionable basis. The spirit of investigation has taken hold of this problem in this country and abroad in a most encouraging way and to an extent but little appreciated by the average ventilating engineer. The physician and the biologist, as well as the engineer, are actively at work in a serious attempt to solve the problem.

As a Society, the aim of which is to establish ventilation and other standards, can we do better than to give substantial backing to a serious effort to determine the merit and essentials of ventilation? No successful attempt can be made in the light of recent investigations to maintain that the present-day standards are scientifically based or that they cover all of the essentials of ventilation. How, then, can we be content to go on designing systems of ventilation, valuable though they be, if it is possible by study and investigation to make them more efficient and complete? Would not this Society be in a vastly stronger position in advocating legislation requiring ventilation if a more scientific, more generally accepted, and entirely defensible basis were reached as to what constitutes proper ventilation?

Any member of a committee of this Society charged with the duty of obtaining the passage of a ventilation bill in one of our State legislatures can give eloquent testimony to the difficulty in the work of the committee due to the confusion wrought by those advocating different phases of ventilation. To no one thing may be more surely attributed the failure of the Committee on Legislation on Factory Ventilation in New York State to secure a bill requiring ventilation of factories than to the confusion produced in the meetings of all parties interested when the volumetric and CO_2 standards were attacked, and temperature, humidity and elimination of dust were separately advocated by others as of equal or more importance than air volume, until finally a member of the committee representing another organization associated with our committee exclaimed that he must first be convinced that there was such a thing as ventilation, or that it was of any value, or that its essentials were known by anyone.

A not unlike experience frequently confronts the engineer when called upon to design a heating and ventilating system for a hospital. Hospital superintendents and hospital experts are not rare who invariably advocate the omission of a fresh air supply system, and there are those who advocate the omission of both fresh air and exhaust systems, entire dependence for ventilation being placed upon the windows.

If, then, the lack of scientific data and of public education is a handicap in securing proper laws requiring ventilation and proper ventilating systems for hospitals and schools, is it not worth while doing everything possible to secure the necessary data and to

assure ourselves that the bills and installations which we advocate are in every sense and to the last degree proper? No member of this Society is afraid, as is sometimes hinted outside, of the effects of such an investigation upon our business, for the business will be immensely helped when it has an indisputable foundation supported by biologists, physicians, scientists, and engineers.

Fifteen or twenty years ago the questions of treatment of water and sewage were in a worse condition, largely a matter of speculation. The problem was attacked by the biologists and water-works engineers with the result that for some years the proper treatment of water and sewage has been little more than a matter of the application of known and accepted formulas and rules. The situation as to milk is being solved in the same way. Is there any reason why the same enviable condition should not prevail as to ventilation?

It is believed by many that outdoor air, especially in the country or on the sea, where greater freedom from dust, a less amount of CO_2, and an increase in ozone may be found, is the most healthful air which is possible to be had, but Dr. Luther H. Gulick asks why it may not be possible, during the heating season, to improve nature's supposedly best air, pointing out that in but a very few cases do we use nature's products unimproved. For instance, we filter or aerate the greater portion of our water, we cook our food, we build expensive habitations and we dress to protect ourselves against nature. In this day of advanced civilization we find it desirable to surround ourselves with artificial conditions.

We hear a great deal of open air schoolrooms, in connection with which 95 per cent. of the credit for the results secured is given to the fresh air, but a brief consideration of the subject may well raise the question whether this is a reasonable assumption. Usually a well designed schoolroom with the best possible exposure as to sun, etc., is selected. A small class with a carefully selected teacher is used as the subject. Shorter lesson periods prevail, and rest, sleep and exercise periods are introduced. Special diet kitchens and diets are often provided. Additional medical attention is given to the children and skilled nurses look after their welfare. Their homes are visited and suggestions are made that the conditions therein may be

as healthful as possible, and finally an abundance of air is available.

But is it not quite probable that the same methods applied to the same class in an efficiently ventilated standard classroom would bring about equally satisfactory results, or that several of the dozen conditions differing from those of the standard closed classroom might be quite as important a factor in the results obtained as is the cold air? The results in some proposed open-air classrooms in which all other conditions are to be the same as in the closed rooms will be watched with much interest.

There can be no question as to the value of a frequent flushing out or "perflation" of the rooms with cold air or the subjection to sunlight of all occupied rooms, if for nothing more than the germicidal properties of outside air and sunlight. Also, there is every reason for the utilization of natural or window ventilation just as far as possible, but therein is no ground for allowing any school, hospital, place of assemblage, etc., to be without an efficient system of artificial ventilation, for it can be maintained that there are very many days when natural ventilation is not efficient or is not practicable because of weather conditions or lack of a breeze. Then, too, in a large building the breeze strikes but one, or at the most two, sides of the building.

If equally good or better results in both studies and health could be obtained in closed rooms, it would doubtless be more agreeable to pupils and teachers, but if this would involve smaller classes, selected teachers, rest and exercise periods, and other attentions given the pupils of the open-air schools, it would mean a seriously increased school budget. If the ventilating system of the past lacks some detail necessary to the best possible conditioning of the air or possesses something which to the slightest degree damages the air, as is sometimes claimed, we should know it at once.

Without any attempt to present their relative merits, some of the important features of ventilation now advocated by different authorities are stated below.

First in general acceptance in the past, and undoubtedly in the future, may be mentioned air volume. It is only comparatively recently that anything more than a certain volume of fresh air supplied and an equal amount of vitiated air withdrawn was considered essential to ventilation. It cannot now be maintained

that this in itself is sufficient to constitute efficient ventilation, but neither can it be denied that this is the basis of efficient ventilation, whether the air be supplied by natural or artificial means. Whether the volumetric standards generally accepted are proper and essential may be open to question and investigation. These standards have as their basis the maintenance of a certain proportion of CO_2 in the occupied apartment. It may be possible that a less volume of air properly conditioned and properly introduced would give the desired results, or conversely, it may be that because of the desirability of air movement (as referred to below) or for some other reason a larger volume of air may be required. Herein lies a field for study and investigation by practical means over a long period of time with a large number of subjects, but an investigation involving many difficulties.

Room temperature is becoming the subject of much study. Seventy degrees are said to be too high as a standard for room temperature. Of late 68 deg. have been gaining in favor. There are those who propose to lower the temperature still further. Having dropped from 70 deg. to 68 deg., is there any reason why we should not drop to 66 deg., to 64 deg., or even to 60 deg.? What governs the desirable point or how shall it be determined? It is suggested by Dr. Gulick that possibly there may be an advantage in a methodical variation of temperature, that is, having adopted 68 deg. as a standard, the room temperature should be dropped to say 50 deg. for a few minutes, perhaps once in two hours in the case of the schoolroom, the occupants of the room being active during this period. A variation of temperature affects the blood pressure, tones up the system and is known to be helpful in the treatment of pneumonia, typhoid and delirium.

The common demand for comfort may be depended upon to prevent too low a minimum standard, but the effects of too high a temperature, although more serious, are not so quickly noticed or so well understood. The temperature often creeps up to a serious degree without coming to the attention of the occupants of the room. The temperature may even reach a point which will cause a rise in the body temperature and also serious functional disorders. The blood which should be serving the brain may be forced to the surface of the skin to give off heat, and dullness will then follow.

The question of temperature is intimately linked with the question of humidity. Here again there is but little of agreement as to the value or importance of artificial humidification or proper degree of humidification. It may be stated that the normal relative humidity out-of-doors averages around 50 to 70 per cent. with large and frequent variations, and a desert would rarely be found with a relative humidity of less than 30 per cent. It is not uncommon, however, to find our schoolrooms, offices and other apartments with a relative humidity as low as 15 per cent. to 20 per cent.

It is pointed out that to go constantly back and forth from such a condition to the outdoors with its much higher relative humidity subjects a person to a series of extremes most trying and injurious. In refutation of this statement an able authority points out that outdoor air, when heated in the respiratory tract, becomes just as lacking in relative humidity as the dry air within our apartment.

The nearest to an agreement obtainable on the proper relative humidity is that it should not be less than 30 per cent. or over 80 per cent.; 50 per cent. is largely used as the desirable standard, but with what real authority? What harm is done when the frosting of the windows compels a reduction to say 30 per cent.? Doubtless there is some one point or some limited range better than another. Is it worth while determining and how shall we do it?

With a higher humidity than has been customary in the past we can doubtless adopt a lower temperature, but not with a resulting saving in fuel, as has been stated in public prints. A simple calculation will demonstrate that approximately four times as much fuel is required to evaporate the water required to produce 50 per cent. relative humidity at 68 deg. temperature in the schoolroom as is saved by reducing the room temperature 8 deg. To the engineer designing ventilating systems it would be most helpful if data of acknowledged reliability were available as to the value of humidity and the proper percentage thereof.

Movement of the air is said to have much to do with personal comfort. Persons confined in a limited space without ventilation until the point of discomfort and lassitude was reached because of high humidity and high temperature, or possibly because of the depletion of oxygen in the air, have been instantly revived

by the circulation of the air within the chamber by means of fans therein. Undoubtedly a film or envelope of air may form about the body, which, undisturbed by a current of air, will reach a temperature and humidity sufficient to produce serious discomfort. Probably much of the pleasure felt in the summer breeze is due to the carrying away of this body envelope and the tonic effect of the air on the skin. Between the limitations of such a condition on the one side and drafts on the other, what shall be done to produce an ideal condition as to air movement during the heating season? Indeed, what constitutes the ideal in this direction? Interesting references to the subject of air movement will be found in an admirable paper on "The Ventilation of Sleeping Cars," by Dr. T. H. Crowder.

It is said by some that the heating of air robs it of some vital force, changes it in some mysterious or unknown way, or adds something undesirable to the air, this complaint being especially addressed to steam blast coils. It may be that a sufficient amount of fine dust containing organic matter will pass through the filter or otherwise reach the steam-heated surface, producing ammonia in harmful quantities, or it may be that some of the oxygen or ozone of the air is consumed by the process of oxidization of the dust.

Eliminating the question of dust for the moment, can we assert that the air is in no way injured when warmed by means of low-pressure steam surfaces? Or can we assert that no injury occurs to the air in passing through hot-water coils at a temperature of 160 deg. or less? If there is any injury due to the heating of the air, to what temperature can it be heated or with how hot heating surfaces can it come into contact without injury? If the air be first filtered, is it still necessary to limit the temperature of the heating surfaces to a point below that of low-pressure steam? Upon what scientific or experimental basis do the answers to these questions rest? Without such data how shall we meet the contention that dependence upon window ventilation with its unheated air, drafts, dust, etc., is preferable to partial dependence upon the ventilating system?

Ordinarily we think of the air as composed of approximately 78.30 per cent. nitrogen; 20.70 per cent. oxygen; .04 per cent. carbonic acid; .01 per cent. watery vapor. In reality the air contains other constituents to which but little consideration has

been given in the study of ventilation problems. One of these, ozone, is known to be a most active element, and it is now being quite extensively used in the treatment of pneumonia.

In the past a great deal of dependence in estimating the efficiency of the ventilating system has been placed upon the determination of the amount of CO_2 in the air, 6, 8 or 10 parts CO_2 in 10,000 parts of air being regarded as proper standards for hospital, school and factory ventilation, respectively, but since it has been discovered that a person feels no discomfort in an atmosphere containing two hundred or more parts CO_2 in 10,000 parts of air if the temperature and humidity are kept within certain bounds, less dependence is placed upon the CO_2 standard and more emphasis is placed upon the need of proper temperature and humidity.

Is it not possible that the full significance or effect of some of the other gases in the air, or the inter-relation thereof, is still unknown to us, or that there are even other gases still unknown, which in some way or measure may have a bearing upon the subject of ventilation, or the subject of air warming? This is essentially a subject of investigation for the chemist or the biologist rather than for the ventilating engineer, but like other problems, it can best be solved by a harmonious working together of the two.

Not until recently has the serious side of the dust problem been fully appreciated. Formerly it was regarded as an annoyance. Now it is realized that it is a problem with several important phases. Dust is an irritant and a disease carrier. Breathed into the respiratory tract it may cause an irritation or even actual abrasion producing a veritable culture bed in which the germ-laden dust may find lodgment. Dust is the great producer of colds. We are all acquainted with the reference to the "deadly duster." And yet in a great many of our school building and hospital ventilating systems no provision is made for filtering the air. Even where the air is filtered it is usually by means of cloth filters of questionable value.

Still less often is the air taken from a proper elevation above grade. Commissioner of Labor of the State of New York, Hon. John Williams, in his last annual report made the following statement regarding the dust content of the air at street level and fifty feet above:

"The Department secured air samples at about one foot above sidewalk of a wide street near the river front, and shortly after the street had been swept by the Street Cleaning Department. The day was clear and sunny, the weather was mild; the analyses showed as follows:

Total solids (dust)	30 grams per million litres
Oxidizable organic matter	11 grams per million litres
Ammonia	1 part per million
Carbon dioxide	4 parts per 10,000 volumes

Analysis of sample taken about fifty feet above the same street on a roof showed:

Total solids (dust)	5 grams per million litres
Oxidizable organic matter	0.48 grams per million litres
Ammonia	nil
Carbon dioxide	3 parts per 10,000 volumes

And yet in the case of many school buildings the air is taken into the school buildings approximately at grade and passed into the schoolrooms without filtering.

Recent experiments give substantial basis for the belief that the vegetable matter combined with the dust of the air coming into contact with heating surfaces above 160 deg. or 170 deg. distils ammonia, carbon-monoxide and perhaps other gases, in some cases to a harmful degree. It would seem as though this could be best prevented by proper washing of the air or by a limitation of the temperature of the heating surfaces to 160 or 170 deg., or by both processes.

The question of organic matter in air which has been breathed, which question has been practically ignored of late, may still be worthy of further study as evidenced by the recent investigations of Professor Rosenau.

It may not be improper to raise a question as to the relation of violent exercise and hard work to ventilation. Have we sufficient data and do we use what we have in cases requiring it?

The cooling of occupied apartments is said to be desirable and perfectly feasible, and it is stated that the heating or ventilating system may in part be used for this purpose, that there is no more reason why we should heat our apartments in winter than that we should cool them in summer, and that this is especially desirable in hospital work. And yet a certain hospital contemplates removing a system which cost a very large sum, not because it would not maintain the desired temperature and rela-

tive humidity with any outside weather conditions, but because the effect of the cooled wards was not believed to be of as much value clinically as the free use of the sea air through open windows. Observations were made on the patients and on the nurses, records being made every fifteen minutes in the case of the nurses. Complaints of headaches were frequent among the nurses while using the cooling plant and the prevailing cellar-like condition was objectionable. Evidently no small problem presents itself in the constantly increasing agitation for combined cooling and ventilating systems.

The value of direct radiation, because of the effect of its radiant heat, which is compared to the radiant heat of the sun as desirable and healthful, is a question worthy of serious thought.

Some interesting experiments have been conducted to demonstrate the effect of ventilation on metabolism, notably those conducted by Drs. Benedict and Milner at Wesleyan University. Further tests along these lines are to be made by Dr. McCurdy at the International Y. M. C. A. Training School, at Springfield, in which it is hoped that the relation of ventilation to exercise may be demonstrated. A system of ventilation and humidification is available in the gymnasium of this school for practical experimentation.

The problem of the best method of testing the effect of ventilation and its different elements is not the least of the ventilation problems. The psychological element enters so largely that calorimeter tests or measurement by means of ergographic tests are not generally acceptable. No other acceptable method of measuring the effect of ventilation upon the individual has been suggested.

The method of determining this which finds the most favor is that proposed for the work of the Special Committee on School Ventilation in which it is proposed to take one or more large school buildings occupied throughout by children of the same grades and condition, treating one-half of the building in one way and the other half in another way, carrying on the treatment for a period of months and measuring its effect by the relative standing of the pupils and their relative condition as to health, weight, etc., as described in the report of that Committee.

The Society is to be congratulated that this step has been

undertaken in connection with school buildings and much that is learned in connection therewith will be valuable in general ventilation problems relating to hospitals, homes, churches, theatres, mercantile establishments, etc.

Briefly summarized the phases of ventilation now believed to be worthy of serious study are as follows:

1. Volume of Air. Our present standards are questioned. By a proper study of temperature or humidity could they be decreased or should they be increased?
2. Temperature. Our present standard (68 deg. for the schoolroom and home) is said to be too high. Shall it be lowered and, if so, to what point?
3. Variation of Temperature. A periodical reduction of temperature is said to be desirable.
4. Humidity. Is artificial humidification of occupied apartments desirable, and, if so, to what degree?
5. Movement of Air. This is said to be desirable. When can it be employed and to what extent can it be carried without involving injurious drafts? What of a frequent "flushing out" or perflation?
6. Heating of the Air. May the air be harmed or in any way affected in the process (assuming the air to be free from dust)?
7. Cooling of the Air. Is this desirable in occupied apartments and will it involve undesirable attending features?
8. Dust. It is stated that dust is extremely harmful. What is its effect, how best eliminated, and how generally should such means be employed?
9. Organic matter from the breath or body. Its nature and effect. What of odors from similar or other sources?
10. Chemistry of the Air. Is there anything connected therewith worthy of further investigation? What of ozone?
11. Relation of ventilation to exercise and work.
12. Methods of determining the effect of ventilation and its different elements upon the individual.

Although many of the so-called failures of ventilating systems in the past may have been due to inexperience of the designer, and many more were doubtless due to lack of skill in operation, it is believed that much of the condemnation of artificial ventila-

tion heard from eminently reliable medical authorities and others is due to the failure of the ventilating engineer to give as much attention to the conditioning of the air as to its volume. And when this phase of the problem is reached, disagreements are met with on all sides, not alone as to whether artificial ventilation is of any value but as to what constitutes proper ventilation. When officials connected with a great hospital condemn a ventilating system and use direct radiation in preference, when other large hospitals build new buildings without such ventilating systems as we would advise, and when expert medical authorities discredit much of the modern artificial ventilating system, it is time we learned the real facts. If we are wasting the hundreds of thousands of dollars that we are spending annually upon ventilating systems, we should know it, or if these disbelievers in the artificial ventilating systems are walking into error we should have the proper data with which to convince them.

On the other hand, if we have overlooked or not fully understood some of the essential elements of ventilation, the quicker we have the necessary data the better, so that the maximum of results may be obtained.

It cannot be denied that the engineers are providing ventilation fulfilling the existing standards, but these standards are not of their creation but were given them by biologists, physicians and scientists in the past. Questions of the percentage of oxygen required, percentage of CO_2 permissible, effect of temperature and humidity, question of organic matter in the air, etc., are not engineering questions. It is but the duty of the engineers to meet those standards which are demonstrated and given to them by the biologist, physician and scientist.

If, therefore, the apparatus provided by the engineer has failed to give satisfaction it is not that the apparatus or engineer has failed but because the standard provided them has failed. If this is a fact, the biologist or physician should determine wherein the existing standards are wrong and they should determine new standards supported by authoritative tests and experiments. Then the engineers may be trusted to provide ventilation fulfilling the new standards. In undertaking to solve these problems the hearty co-operation of the engineers may be depended upon.

Ventilation has accomplished so much which may be positively demonstrated that we may repose confidence in the work of the

past, but the problems remaining to be solved are worthy the serious consideration of the membership of this Society and the cordial support on the part of the Society of the work of its Committee on Schoolhouse Ventilation.

In the meantime we feel assured that the welfare of humanity will be advanced if we advocate the thorough ventilation of all buildings by means of a supply of air of the generally accepted volumetric standards, with a careful regard to elimination of dust, provision for humidification, and for the prevention of excess temperature. Some air movement and a flushing out of the rooms is doubtless desirable. With this as a working basis the problems or questions in dispute should be studied as carefully and rapidly as possible. We would not see a backward step taken, such as would be involved in an abandonment of the present standards of air volume, but with the above as a starting point let us study the new problems of air conditioning, that the splendid achievements of ventilation to this time may be improved upon.

It would seem as though this meeting of the Society would fall short of its opportunities and fail to reach the fullest possible success if it did not effectively recognize the active interest which this subject is awakening.

DISCUSSION.

THE HYGIENE OF VENTILATION.

(Discussion, chiefly by Members of the Medical Profession, Invited Guests of the Society, on the Preceding Papers and Reports.)

Dr. W. Gilman Thompson*: Mr. President and gentlemen: I appreciate very much being asked to come here and take part in this discussion. I think it is very desirable that medical men and those interested in these practical ventilation problems should get together; and I being one of those medical men alluded to by our friend, Mr. Kimball, I feel doubly interested in being here to hear his discussion.

* Professor of Medicine in the Cornell University Medical College in New York City.

When one is called on to give testimony one should present one's credentials; and as far as the problems of ventilation are concerned, mine are that I have worked personally in three of our largest metropolitan hospitals, where elaborate systems have been put in of the closed ventilation type and are now in disuse, it having been the experience of medical men that they are pernicious for various reasons.

Ventilation problems can be stated from two points of view; one is the physical and one the physiological. I have undertaken the physiological study with instruments of precision, by studying the effects of different atmospheres on the individual; and that method I admit has been much neglected by physicians in regard to accurate determinations. A number of us lately have been trying to find out *why* it is that one feels better in fresh air than in foul, and we have found some very interesting things in regard to blood pressure. Without going into detail, I will say that we have instruments for measuring the blood pressure of the human body. The normal adult blood pressure at the wrist, the radial artery, is 140 millimeters of mercury. If the pressure falls much below that standard, it means poor blood supply all through the body, and if it rises above there are other symptoms. As between fresh and foul air we found most interesting and surprising variations of blood pressure, particularly in children. In children the normal blood pressure is about 100 millimeters of mercury. A child having pneumonia, kept for 24 hours in a closed ward, with all the modern ventilation appliances and the best air that could be so supplied, had a subnormal blood pressure. Being put outdoors in the fresh air in two hours the pressure rose to normal and so remained while the child was in the fresh air. Here is another diagram, illustrating the same thing and made by Dr. Hoobler. Every elevation here shown is a restoration to the normal blood pressure. Here is a particularly striking chart. This child, also having pneumonia, had been out of doors for some hours; the blood pressure was very nearly normal. On being taken indoors, within only 30 min. the pressure dropped to a very dangerous point, a subnormal pressure of 80 millimeters of mercury instead of 100.

With outdoor air the delirium of patients clears up remarkably, and such air has a remarkably beneficial effect on the activity of the secretions and other special functions. A great

deal has been said in regard to the effect of humidity, and just at present that is a fashionable thing in regard to ventilation. Why, according to some writers whose articles I have read, you might have the atmosphere surcharged with carbon disulphide, marsh gas, and carbon dioxide provided the "humidity" is "comfortable." These are all gases of the human intestine and capable of being exhaled into the air.

I still believe that carbon dioxide affords something of a measure of the exhaled impurities in the atmosphere of a room. While I admit that humidity has something to do with the sensation of comfort, there are many more important factors than this.

I came into this room after an hour of your meeting and this air was very uncomfortable. Physicians also often come together and talk ventilation problems in the most atrociously ventilated rooms! It was uncomfortable when I came in this room, but I stayed here and heard this discussion on humidity and soon became much more "comfortable!" Personal comfort is a poor criterion for estimating the fitness of air to breathe. Where one is dealing with children, who are doubly sensitive, one's lungs and nose afford an infinitely better test of atmospheric purity than humidity. You can feed a dyspeptic on canned corn, but there is nothing "uplifting" in it any more than there is in canned or superheated air for an invalid. I still must differ from Mr. Kimball on the extent to which air is sometimes superheated. He says it is difficult to raise it to 400 deg. F. The records show that was really the standard at the Presbyterian Hospital at one time. But some subtle change takes place in it. You cannot thrive on such air. The growing child needs to have the very best conditions for its development and vitality, and for the activity of its circulation. This is a very wide subject, but I will stop here.

May I say one word more? If the Board of Education, those in charge of schoolroom ventilation, would only sit a little time in the schoolrooms and not rely so much on hydrometers and thermometers and that sort of thing, we should soon come to much more practical results.

Prof. C.-E. A. Winslow*: Ventilation has been extensively discussed in the public press recently. I do not believe that the

* Associate Professor of Biology, College of the City of New York.

daily paper is the place to settle a complex technical subject of this kind, and I doubt if the results reached in such a way are likely to be of scientific value or are likely to prove really helpful in public education. The conference this afternoon, however, cannot fail to prove of great value, and it is a most encouraging thing that your Society should have taken up the question with the breadth of view and the earnestness that have been shown to-day.

None of us is prepared to deny that many ventilating systems have proved failures. We know that something is wrong, but we differ as to the diagnosis and the remedies. It has been assumed by many that the trouble has been with the whole practice of ventilation and that it should be discarded in favor of open windows. "Back to Nature" is the cry. This I believe to be a wholly mistaken view and as unreasonable as it would be to conclude that because the New York water supply is sometimes dirty we should wreck our aqueducts and tell every citizen to dig a well in his own back yard. Back to Nature is seldom the solution of any problem.

All along the line civilized man is improving upon Nature and there can be no question that, when we determine just what quality of air we need, it will be feasible to supply that air to the occupants of rooms by the use of mechanical devices. On the other hand, it is quite impossible to control the condition of the air in an inclosed space in cold weather by opening windows, for, if those at a distance from the windows feel comfortable, those near the windows must inevitably be exposed to unendurable drafts. The trouble has not been with ventilation per se. Neither in my judgment has it rested mainly with the designing engineer but with the sanitarian who has failed to tell the engineer what to do and with the janitor who has failed to operate the plant after it is installed.

Up to two years ago the designing engineer was told that all he had to do in order to ventilate a school was to supply 30 cu. ft. of air per minute. Nothing was said, in particular, to him about the quality of the air. Even to-day, the sanitarian is unable to give a full or satisfactory answer to the question as to what sort of air the engineer should furnish. We do know that a temperature of over 70 deg. is distinctly harmful. We know that too much humidity is bad and we are reasonably sure

that too little humidity is also bad. Just how much or how little we cannot say. These are all points which can be solved, however, and their solution is one of the most interesting problems of the next ten years. The fundamental aspects of water supply, sewage disposal and garbage disposal have been practically worked out. The live question in sanitation at present is this question of air supply.

We must determine exactly what degree of temperature, and what amount of air change, is most favorable for the human machine and when that is known there will be no difficulty at all in designing systems to provide that kind of air. We shall then need to emphasize the fact that it is a poor plan to build an elaborate mechanical system and allow it to be inefficiently operated, and we must turn attention to the administrative problems in the running of the plant after it is installed.

The first thing we need, however, is more light as to the physiological effects of air conditioning upon the human body.

Who is going to furnish the answer to these questions? I believe it will be primarily the ventilating engineers, and the public health experts, for whom the question of air supply has a direct and immediate interest, rather than the medical man whose interest lies in wholly different lines, or the physiologist whose attention is directed rather to the theoretical side of physiology than to immediate sanitary applications. The engineer and the sanitarian will need to call in the medical man and the physiologist, just as the water supply engineer has solved his problems with the coöperation of the chemists and bacteriologists.

The question of air supply is a public health question and is going to be attacked by those who are primarily interested in public health, and particularly by the engineer, who, in order to design his system adequately, must have more information than he now possesses. He will call in experts of all sorts to assist him, but he is likely to be himself the pioneer in this field. It is to your Committee on School Room Ventilation and to the Committee, on the same subject, of the American School Hygiene Association, and to the committee shortly to be formed by the Sanitary Engineering Section of the American Public Health Association that I look for important constructive work in the next few years.

Dr. James H. McCurdy*: Mr. President, I hope I can, in the few minutes I have, be of the most help and interest to you men by simply stating briefly the one point of contact; those who are studying in Springfield the problem of ventilation from the standpoint of a group of men, some one hundred and ninety of them, who are taking vigorous exercise under direction. Thus we have felt that in using these men who are taking exercise for about two hours daily, and studying the conditions, what you might call exaggerated conditions, we may get at some facts that it would be impossible to get from hospital conditions or from school room conditions; so that we have a plant equipped there so that we can control the humidity anywhere from 20 per cent. relative humidity up to at least 80 per cent.; we can control the temperature automatically, so that we can run that up or down. We have close control of both temperature and humidity. We are studying the effect upon the individual of high humidity and of low humidity, of low temperature and of high temperature. We are taking blood pressure tests, heart rate tests, and trying to find out what the effect upon these individuals of variations in temperature and humidity really is. We have just got our plant equipped, so that we cannot give you definite reports with reference to these particular problems.

I was interested in what Dr. Thompson had to say about the blood pressure of the individual. We have been following that for a series of years and find that the young men that we are dealing with have a considerably lower blood pressure than he gave, 140 millimeters of mercury. We find a pressure of different grades, running from 110 millimeters up to 124 or 130, and boys in the high school running from 110 to 120.

A Member: How many cases of the boys in the high school?

Dr. McCurdy: We have to group roughly on that. We have taken more than 100 boys.

The Member: Taking each boy more than once?

Mr. McCurdy: Yes, the boy's condition is taken four to six times each year. It seems to me it is one of the ways of checking the problem that we must learn what the effect of living under indoor conditions is, with the active exercise conditions;

* Associated with the International Y. M. C. A. Training School, Springfield, Mass.

and that if we can see certain results there we may fairly assume that those will help, at least, in determining the conditions for health of the children who are studying quietly in the schoolroom. Personally I feel that we are obliged to live under indoor conditions part of the time, and we must learn how to live there. I do not know whether we ought to have a low or high relative humidity. I do know that it is uncomfortable for a young man to work under low humidity, below 25 per cent. I do know that when we run the humidity above 70 per cent. they feel sticky and do not like it. There is a point in there somewhere where they get greater comfort. Just what that point is I don't know. I do know when the temperature rises above 70 deg. individuals are uncomfortable. We are trying to get the room temperature in which they exercise down to 63 deg. F. We are varying the humidity, but those are the limits, clinically, it seems clear that we cannot go below 25 per cent. and feel comfortable. We cannot go above 70 per cent. in relative humidity and feel comfortable. We cannot go above 70 deg. of temperature and be comfortable and we cannot go particularly below 50 and be able to do the things that we have to do indoors.

There was one thing I forgot to speak of. We have both the plenum and exhaust systems in our circulation and we put in a bypass so that we can recirculate the same air, and part of the time we recirculate and use what one of the speakers has called canned air.

C. Ward Crampton, M. D.*: The problems of the ventilation of the school rooms of New York City have been studied for many years by the Bureau of Buildings, of which Mr. C. B. J. Snyder is the head, and the Department of Physical Training. Two years ago when the present popular agitation began, it became evident to me that many of the classrooms were overheated and that the then existing standard, 68 deg. to 73 deg., was too high. Not only was it too high but temperatures of 76 deg. and 78 deg. were common. Accordingly the standard classroom temperature was lowered to 65 deg.-68 deg., and the gymnasium temperatures to 60 deg.-65 deg. This naturally diminished the overheating, but it has not eliminated it.

The present agitation against our present mode of forced ven-

* Director of Physical Training, Department of Education, New York City.

tilation is mainly, if not wholly, the result of observation of these overheated classrooms, and some classrooms where the defective apparatus is delivering but little fresh air. No one who has taught in or observed a classroom at its proper temperature—65 deg.-68 deg.—with the plenum systems working properly has ever complained to me that the ventilation has been poor, for it has not been poor.

The overheating is due as a rule to defective diaphragms in the direct radiation control and other failure of the thermostat control. The occasional failure of the fan and duct mechanism is due to faulty control or lack of much needed repairs. The worst ventilated rooms in the city, where I have found the air actually foul, are in the old buildings where we do not have the plenum system and the windows are relied upon for good air. It is evident that window ventilation can never furnish sufficient air for 40 to 60 children in a room unless some are subjected to dangerous drafts of cold air. The result has always been that drafts are avoided and the air becomes bad.

The faults I find with the present system are as follows:

1—It is not automatic. It requires constant expert care, testing and renewal of important parts which quickly deteriorate. This is a matter which should be taken up most seriously by the members of the heating and ventilating profession. We cannot afford, it is clear, to pay more money for expert janitorial service, and, while in the main the janitor engineer is expert and vigilant, yet there cannot fail to be exceptions. I maintain that there should be developed a system which should be made automatic in fact as well as in theory, and for this we must rely upon the further efforts of this distinguished body.

2—It does not insure against overheating.

3—It does not control humidity.

Automatic control of water content of air supplied by the plenum system must be incorporated in any system of ventilation that is designed to meet the needs of school children. Raising air 40 to 60 deg. in temperature without adding sufficient moisture will produce a dry air which is harmful.

4—We need a proper re-circulation system with adequate air washers. I am convinced that this will be the system of the future, for I know no reason why it cannot be made sanitary. Moreover, it will save sufficient in coal bills to meet any additional cost of installation and maintenance.

5—I am convinced that the amount of air per child per minute should be doubled if not trebled and that the circulation of air in the room about the child should be much more rapid than our present standard provides.

In closing I wish to state that the school systems of the United States owe to you individually and as an association a very great debt, for without your services it would not have been possible to carry on our educational procedures under the conditions imposed by the city congestion of to-day.

Dr. Thomas S. Carrington*: I am very glad to be here with you to-day, but I am not particularly glad to be asked to speak, for the reason that, after working for two years for the National Association for the Study and Prevention of Tuberculosis on problems of ventilation, I find that I know less about the subject than I thought I did when I began the work. I am speaking, of course, of the biological and the physiological side of the problem. The fact of the matter is that very little is known about the effect on the human body of many atmospheric conditions. Take, for example, our knowledge of the effect on our bodies of the moisture in the air that we breathe. Humidity is perhaps one of the easiest factors of the atmosphere to study, and still there is a great difference of opinion among investigators as to what the relative humidity should be to produce a healthy atmosphere.

The reason why our knowledge of ventilation is in such a chaotic state to-day must be that long ago many statements which were not true were made regarding the problems of ventilation, and these statements were copied and repeated over and over in books until they were accepted as facts. In my opinion the entire subject of ventilation needs to be investigated at the present time and carefully studied before standards for the

* Assistant Secretary of the National Tuberculosis Association.

proper ventilation of buildings can be made that will be acceptable to scientific men.

As an example of the impossibility of agreement among experts at the present time, take Mr. Kimball's statement on page 5 of his paper. There he says, "There is every reason for the utilization of natural or window ventilation just as far as possible, but there is no ground for allowing any school, hospital, place of assembly, etc., to be without an efficient system of ventilation, for it can be maintained that there are very many days when natural ventilation is not efficient or is not practical because of weather conditions or lack of breeze." Refusing to accept this statement are many well-known medical men who do not want ventilating systems in their hospitals, and who object to their use where such systems have been installed. The trouble is our lack of knowledge regarding the whole problem of ventilation, and I hope an investigation can soon be made, the results of which will be acceptable to both engineers and physiologists.

Mrs. Stephen S. Wise: I have only a word to say, and my own point of view is so different from the point of view of the professional and trained engineer that I hardly believe you will care to hear it. Putting it in the briefest possible terms, I venture to express my own belief and to say that all systems of ventilation which I have thus far seen in operation seem to have failed. I hold in my hand a number of reports concerning the ventilation system in the public schools of New York that have been investigated. Among 32 schools in which the ventilating system obtained, there was not one in which it worked properly. There were times when the temperature was low enough, but in all cases the air was none the less stale, flat and unprofitable, and always most unpleasant. All rooms were being subjected to one treatment. The result was that when classrooms on the shady side of the schoolhouse registered a temperature of 68 deg. or 70 deg., the rooms on the sunny side were unendurably stuffy, registering as high a temperature as 75 deg. to 80 deg. Therefore, I have come to the conclusion that until the ventilating systems are perfected, or in any event greatly improved upon, they are really hurting the children instead of helping them. If the system is introduced, the least that engineers can do is to see to it that it is used properly and effectively. This I know, that as it is at present used, children are being hurt

by it. They are breathing dust and inhaling bad air, and thus they are getting the very things which the school ought not to give them. In the schools to-day in which the ventilating system obtains there are temperature and atmosphere which none of us would tolerate in our own homes for an hour, and these children are subjected to this intolerable condition for five hours and more daily.

I do hope that this body of experts will reach some conclusion which will make things better for our children. I believe no room in which children are confined should have windows closed, thus excluding fresh air in motion,—the two vital needs of human beings. And when conditions are such that a ventilating system must be and that requires closed windows, there ought always to be fans in the rooms to keep the air in motion.

Prof. Frederic Bass*: I have had an opportunity to read rapidly the paper read by Mr. Kimball before coming to the meeting; and I want to say that it seems to me to be the best summary of the question that I have ever seen. As I read it over, I picked out a few points upon which I wish to make some definite comments, but in view of the statements which have been made by the eminent speakers who have preceded me, the expressions of diffidence which they have given and the lack of knowledge which they have professed and which I, too, must profess, it seems a little bit out of place to say very much of a definite nature.

I have had experiences similar to theirs. I have sat in with a State Board of Health in the West where regulations for hospital construction were to be considered and were passed. The subject of heating and ventilation was entirely ignored, because some members of the board and the outside physicians who were there for the purpose of consulting for this particular purpose expressed the belief that hospitals would be much better off without a system of ventilation than with one. It seemed to me that it was an anachronism.

In the beginning, it seems to me well to dispose of the supposed problem of communicable disease as affected by ventilation. A specific disease is caused by a specific organism, and we do not ordinarily, with closed windows, find these in the air of inclosed spaces except in the near neighborhood of a speaker, and then only at the time when he is speaking. With air wash-

* Director, Engineering Division, Minnesota State Board of Health.

ing, which would be used where the incoming air was laden with dust, the greatest danger from dust would be at the time of opening the windows, when dust might be raised by the unusual drafts, and which might contain pathogenic organisms.

The known effect of long-continued exposure in poorly ventilated rooms admits of no doubt of the benefit of good air; and we are now engaged in the quest of knowing what good air is; and, to know this, we must have some knowledge of the anatomy and physiology of the human being and apply it.

Dr. Winslow refers to the question of water and sewage purification, the history of which has been very similar to this one. The most common foes which we have are water and air. The engineer has undertaken the problem of water purification and has solved it with the aid of the bacteriologist.

In the same way, the heating and ventilating engineers must rise to the occasion, bring in the physiologist, the eminent man interested in this particular question, and work with him and understand his point of view and produce the structures that will supply air of the quality which is required. Of course we don't know all the factors which are necessary to purify air at the present time, but we need a classic series of experiments similar to those undertaken by the State Board of Health of Massachusetts at Lawrence in 1898, with respect to the purification of water.

There are two physiological effects, two classes of physiological effects, to which it seems to me we wish to direct our attention. Professor Wolf has, in the paper referred to to-day, extremely well presented the effect of ill-conditioned air on the exterior of the body. There are also effects on the interior of the body—the mucous membranes, the respiratory passages and the olfactory branches of the vagus nerve, and its connection with the process of breathing. These things are not beyond the comprehension of the educated engineer; they must be understood by the heating and ventilating engineer before he can apply the apparatus which will remedy the present defects.

One other point which seems to me very important is that before we have solved this problem of good air we might well consider the proper distribution of air. The ordinary school room is now ventilated on the dilution principle. Why not the displacement, which may be secured by using multiple inlets and outlets? Why not multiple points of entrance of air at or near

the desks, and outlets at the ceiling with upward ventilation? We then have a natural method of displacement. It is possible to do that. No doubt it might cost more, but the good things of life always cost more than those which are not so good.

There is a great possibility, it seems to me, in the use of ozone. When problems of quality have been determined, the amount of air to be used in a system of air conditioning and distribution may be considered; and that amount of air has absolutely no relation to the present standards, which are entirely arbitrary, based on the makeshift carbon dioxide standard. It would be better to leave that question alone until new knowledge in regard to air distribution is secured; for, unless we do, complications will be thereby introduced.

It seems to me we are now entering upon a new epoch in ventilating, and one which will depend upon the application of scientific methods rather than that of dogmatic assertion and rule of thumb. I thank you very much.

Mr. H. Thurston Owens*: The gas industry is in the business of producing ventilation quite as much as those connected with the American Society of Heating and Ventilating Engineers, their apparatus consisting of the gas in combustion for light, heat and power. The heat produced increases natural ventilation in a marked degree and many men in the industry who have seen it so successfully perform this function often wonder at the efforts that are being made to enforce compulsory ventilation laws.

It is the opinion of many that should a building be so constructed that there is a large increase of carbonic acid gas at the breathing level in rooms where gas is used for lighting, provision should be made for forced ventilation without reference to the quantity of gas consumed but rather be determined by the number of people and their occupation.

An exhaustive investigation of this subject was made in London by Dr. S. Rideal and reported in a paper before the Royal Sanitary Institute in 1908 as follows:

"(1) Owing to the better ventilation obtained by gas, the products of combustion are not found in the air in anything like the proportion which might be expected, the temperature and humidity in an occupied room being no greater than when the room is lit with electric light.

* Associate Editor, American Gas Light Journal.

"(2) Carbonic acid has not the injurious effect which was formerly attributed to it, but considerable rises in the temperature and moisture content of a room, from whatever source, do have a prejudicial effect upon the well-being of the occupants. Even under adverse conditions of ventilation purposely created for this inquiry, neither the temperature nor percentage of moisture in the room reached a point at which any such effect could be detected by any of the recognized physiological tests.

"(3) It has been established that the products, viz., heat, carbonic acid and moisture, so far as they modify the health of the occupants of a room, are derived from the inmates more than from the illuminant, and that a room of moderate size can be efficiently lighted with gas without sensibly affecting the amount of these three factors.

"(4) While undoubtedly it is important to insure adequate ventilation in domestic rooms, this, with present methods of construction, is better insured the smaller the room. The problem of securing efficient ventilation in public rooms of a larger size has been outside the scope of this inquiry.

"(5) The medical conclusions are in accord with those arrived at from the chemical and physical data, and also demonstrate that the choice between the two systems of lighting does not depend upon hygienic considerations."

While it seems quite generally agreed that CO_2 from combustion is not harmful in small quantities, it is important to note that in a report covering a period of five years D. J. S. Haldane and his associates recommend that the standard for ventilation in rooms where gas is used for illumination be as follows: the proportion of CO_2 at the breathing level not to exceed 20 parts in 10,000 volumes.

The writer trusts that these investigations will receive further attention from those working toward bettering the conditions in factories, and I am sure that the gas industry stands ready to welcome suggestions and to coöperate toward bettering hygienic conditions and bringing about the smokeless, dustless city.

Prof. William Kent: In regard to the criticisms of Mrs. Wise, I think when a charge of that kind is made it should not be extended into a general charge on ventilation of all the schools in New York, but the particular room should be mentioned, and the date, and the matter should be referred to the

Board of Education, which could have an investigation made into the cause of the bad ventilation of each particular room and have it remedied. These general charges that we have bad ventilation all over are not going to bring about the desired result. So I suggest that when anyone makes a charge of that kind she be requested to put it in regular specifications and have it brought before the Board of Education in proper form for an investigation of that particular case, and not draw a general conclusion.

Mr. Wolfe: I understood Mrs. Wise to say that all the schools she visited were bad. Am I right?

A Member: Yes.

Prof. Kent: She should mention the dates and the schools that she visited and they could be investigated.

Mr. Myrick: We learn from Dr. Gulick that ventilation is not necessary, we need only to break up the aerial envelope about the body. Another says: "wash and humidify the air"; another, "open the windows"; another, "use ozone." You can't beat nature, we all know the temperature and humidity don't remain at a fixed condition under natural laws, and we must have air to breathe, and doctors agree that ozone is dangerous and quickens the heart beats. Open the windows and spoil the heating systems. Thus the fads and fancies are answered. I do not believe that 30 cu. ft. of air is necessary or that putting it in at the top of a room is good practice. The temperature of the body is 98 deg., foul air exhaled against a room temperature of 65 to 70 deg. F. ascends like cigar smoke. CO_2 is greater at the ceiling, and the dark streaks there show where the dust has caught as the air percolated through between the laths and floor timbers. Don't bring the foul elements down to the breathing line again and give them another taste like the "family tooth brush." Ventilate from the ceiling, use 10 cu. ft. per person, save the expense of stack heater and aspirating coils, because 50 per cent. of these are not used. The Committee doesn't want to burn the coal and the caretaker is too lazy. Run your chimneys up high. Never mind the architectural beauty, think of the comfort and health of the occupants. Pure air is free, but as now administered it is neither pure nor free, although it is more important than food or clothing.

Keep plants in the room, a good indication of air conditions. A school teacher once told me the air had a bad smell. I put

cologne on a handkerchief and waved it about; the smell remained, proving to her that so long as the school children hung their clothes near frying doughnuts and other odors, no ventilating system would remove the smell.

Mr. McCann: In regard to Mrs. Wise's criticisms of the schools: unfortunately she visited schools at random in New York City, and where a building, for instance, was built 50 or 75 or 100 years ago in part, and part 25 years ago and part 10 years ago, possibly the part that was built 10 years ago or even perhaps 25 years ago had some ventilation, but nothing like what the school of to-day has. But unfortunately she had an idea that ventilation as it exists to-day was represented by what she saw of schools of that character. Naturally the impression was bad. The Board of Education of this city, and doubtless of every other city, welcomes criticisms that are made in a spirit of helpfulness. I hardly think that hers were. She did not give us a fair chance to show a modern ventilated school to her.

To me the schoolhouse is like a factory, where the incoming children are our material; the output consists of more or less well-equipped citizens. Anything, therefore, that will prevent the turning out of imperfect output should be considered very seriously, and if possible adopted. The school house output is of most vital interest to the owners of the factory, the public, as the future welfare of that public itself hinges upon the value and completeness of the training and physical equipment of its children.

The successful manufacturer of to-day does not hesitate to replace the machinery of his plant as often as is necessary to keep his factory abreast of the state of the art, even though that machinery be in good condition and almost new, as he realizes that with antiquated machinery and obsolete methods he cannot hope to compete successfully in the world's market. How much more should the owners of the school factories discard apparatus which the state of the art shows to be inadequate or obsolete.

It is a self-evident fact that while the children and teachers in our schools are working under unsanitary and debilitating surroundings they cannot show the rate of progress that could be made under more perfect and hence more favorable conditions. The loss of time caused by lowered vitality costs the taxpayers large sums, as children thereby are compelled to repeat the work of the different grades, requiring added teachers,

more school rooms, books, etc., to care for the same. It costs about $40 a year to keep and care for each child in the public school, and if the child repeats a year, of course that $40 is practically thrown in the waste-basket.

The loss to the public is also increased by the expense involved in feeding and clothing these "repeaters" for the years thus wasted when they should be earners instead of dependents. Further, the public loses by the lowered efficiency of its future citizens involved in the loss through training or impaired health or lessened vitality caused by such unsanitary conditions of the school room. And I might say further that the loss to the public is increased by the lessened equipment or training of the children, many of whom become discouraged under those conditions and drop out before the end of their training period.

It is obvious that for economic reasons, to say nothing of higher reasons, the best that can be designed should be provided for our schools, for old schools as well as new. The fact that little has been done in this matter of bettering old schools entirely justifies the criticisms that from time to time have been made as to bad conditions in public schools in this and other cities. On the other hand, many of the statements made in these criticisms have been incorrect, as the poorer examples have been selected as proving the impracticability of using any form of ventilation in schools other than by opening windows.

Open-window ventilation has repeatedly been shown to be unsafe, unsanitary and unreliable, whereas properly designed and operated mechanical ventilation is safe, sanitary and reliable, and has been proven such in many cases. I can take you to several schools, private or public as you prefer, where modern ventilation is working successfully and giving satisfaction.

I do not, however, claim that no improvements are desirable in these schools. I am a firm believer in airwashing and humidity control, which none of these schools has, and several years ago I stated on this floor that were the funds available I would install airwashers, etc., in every school in my jurisdiction.

I further firmly believe that we should ozonize the air in connection with ventilation, and it seems to me that possibly ozonizing would enable the use of about one-half the air needed for adequate ventilation with air not so treated. Unfortunately, so far I have heard of no means for controlling the amount of ozone to suit the momentarily varying needs, and also the

amount of such needs has not been definitely determined. There is also the danger with ozonizers that the electric discharges used to generate ozone may, because of overheated terminals, generate nitric acid and nitrous oxide, either of which is dangerous to the persons breathing the same, and too much ozone is also injurious.

These matters are so vitally important to public welfare, that I trust that in the near future tests will be made of such scope and variety that the questions raised here to-day may be settled and the art and science of ventilation may become fixed. Much thought has been given to the character of such tests and the problems presented thereby are not easy of solution.

The deleterious effects of impure air and poor ventilation are slow in appearing, but are none the less disastrous, whereas local conditions of epidemic, such as colds, etc., show more rapidly than do the effects of bad air, and even the excitement created in the children and teachers in connection with experiments made upon them may nullify the data taken in such tests.

This matter is serious enough, in my judgment, to merit a very thorough series of tests being made by a corps of trained nurses and physicians working in harmony with experienced heating engineers, and the value of the results to be obtained would warrant the expenditure of whatever sum may be necessary, either by the city, the state or the nation.

Mr. Chapman: Investigation shows a regrettable lack of legislation for compulsory ventilation of motion picture show places throughout the country, there being very few localities where there is any adequate legislation on this subject, and in most localities there is absolutely no legislation regulating this important matter.

The New York Chapter has had this topic up for discussion, and I believe that most of the members of our society have discussed this question at more or less length, so that it is unnecessary to go into much detail at this meeting.

We all realize the enormous and rapid increase in the number of motion picture show places in New York and throughout the country, together with the large and constantly increasing attendance. We have probably all had sufficient experience in actually attending these places to realize that the existing average condition, as relates to the great lack of proper ventilation, is a decided menace to public health.

I feel that our society has a great opportunity, and also a duty: to go on record in advocating practical regulation requirements for reasonable and proper heating and ventilation of motion picture show places, and to use some definite plan to assist to bring about compulsory legislation on this subject throughout the country.

In order to bring this matter before you in simple form, I will read the report of the committee appointed at the December, 1911, meeting of the New York Chapter on "Recommendations which the Chapter should make in reference to the Ventilation of Motion Picture Show Places," for cities or localities where proper legislation is not in force.

"Your Committee acting from a practical standpoint rather than from an ideal viewpoint advance the following recommendations for legislation to cover *this important phase* of the needed general regulations of motion picture show places.

1. Floor Area Per Occupant.

A *minimum* of 5 sq. ft. of floor area per occupant, exclusive of passageways, shall be provided in the audience hall.

2. Cubic Space Per Occupant.

A *minimum* of 90 cu. ft. of air space per occupant shall be provided in the Audience Hall.

3. Quantity of Out-door Air.

A *positive* supply of out-door air from an uncontaminated source shall be provided the audience hall at all times, while the show place is open to the public, and the quantity of this positive supply of out-door air shall be based on a minimum requirement of 20 cu. ft. per minute, per occupant.

4. Temperature.

The temperature of the air in the audience hall shall be maintained throughout at the breathing line (persons being seated) within the range of 65 deg. F. to 70 deg. F. (except when the outside temperature is such as not to require the air supply to be heated), and the temperature, distribution and diffusion of the supplied out-door air shall be such as to maintain this result without uncomfortable drafts.

5. Direct Heat Sources.

Any good heat source which does not contaminate the air will be accepted to supplement the warmed out-door air supply. Gas heaters or coal stoves are prohibited.

6. *Machine Booth Ventilation.*

Enclosures or booths for the motion picture machines shall be provided with special exhaust ventilation positively changing the air in the booth at least six times per hour, and being entirely independent from any exhaust ventilation of the audience hall. This ventilation shall consist of a number of small metal screened openings near the bottom of the booth, and a metal or other fire-proof flue (size not less than 15" diameter) extending from top of booth and carried to proper place of discharge doors and augmented by mechanical appliance, or otherwise, to secure the results herein stated.

General questions, such as inspection, *method of enforcing the requirements, penalties for non-compliance, etc.,* are left for each town or city to determine.

FRANK T. CHAPMAN, Chairman.
W. W. MACON, THOMAS BARWICK. } Committee."

I might add that since this report was made the committee found that the "Law of the Commonwealth of Massachusetts" relating to regulation of motion-picture show places requires a fresh air supply (with damper control) introduced at the bottom of the machine booth, which has been found to materially assist, *during the summer months,* in keeping the operator in the booth fairly comfortable.

It will be noted by attention to the report just read that, by the regulations recommended (including requiring a minimum floor space per occupant; a minimum cubic space per occupant; a minimum quantity of out-door air per occupant; the control of temperature of the auditorium hall at the breathing line, etc.) the required results from a well-designed heating and ventilating apparatus are assured, without the need of having the law include arbitrary instructions as to design of apparatus. The results are what we are after, and the requirements, as outlined in the report, can be readily measured and violations dealt with.

It must be remembered that this subject of ventilation is definitely bound up with the subject of heating and is affected in marked degree by space conditions governing occupants, etc., and that while ventilation is only one phase of needed general regulations for motion picture show places, it is certainly a most vital one as regards public health.

Mr. Snyder: I hold in my hand a 58-page report of one of

the twenty-five dollar per day investigators. I shall be called upon, undoubtedly, for an official expression of opinion, and therefore will only read a letter which I wrote in 1907, when this matter was up before; and in doing so I think I am well within official courtesy and confidence. In explaining I will say that in the organization of the Department of Education there is a Committee on Buildings, which has charge of the construction and maintenance; a Committee on Care of Buildings, which has charge of operation but *not* charge of fuel, a Committee on Supplies, which has charge of fuel.

(Reads letter.)

That was in 1907. There has been but little improvement since then, because of divided responsibility.

On my way to the office I stopped in a small school building this morning which was equipped 14 years ago. There is an exhaust chamber, the door to which I found open. There is a door beneath the fan for passing into the outer duct for cleaning the apparatus; and this door also stood open. You can imagine how much efficiency that fan was developing. Last week I called at a building and the principal said, "I am very much dissatisfied with the ventilating apparatus of this building." She said, "It does not work at all. It is very uncomfortable." I said, "Madam, you have a full complement here of apparatus and I judge it is all in working order." She said, "Well, I do not think so, and we are very uncomfortable." It was a low-pressure, direct heating apparatus. There was no plenum or exhaust or artificial ventilation of any character whatsoever. She had the open windows to fall back upon and she did not know the difference. That is a fair sample of part of the criticism we receive.

President Bolton: I think it is due to Mr. Snyder to state something of what I have become acquainted with as to other classes of public buildings. Improper operation of ventilating apparatus in our public schools is rare as compared with the conditions obtaining in some other classes of public buildings. It was my duty to test for one of our city departments the heating apparatus installed in the Tombs Prison. I spent the only two days and nights of my honest life in jail, making the test. There are usually some six hundred prisoners in the institution, none of whom is supposed in the eye of the law to be guilty. These and a staff of wardens sleep there during the

night, and not one fan out of the whole number that should ventilate the place was moving during that time, nor, I was informed, had been moving for two years prior to that time. The dust lies thick over the motors, which for some reason or other are not used at all, while the air around the cells, especially in the women's department there, would disgrace a fishmarket.

That may appear to be a remarkable and solitary instance of the neglect of minor officials to make use of what they have been provided with for their own benefit and that of those committed to their charge, but when I tell you that the same conditions are existing in other city buildings of the first order I am sure you will be surprised. On investigating the interior conditions of the recently completed and magnificent Hall of Records, a building which has been constructed by the city with unlimited expenditure and in which is installed a power, heating and ventilating plant of lavish cost and excessive proportions, I found that the blowers installed as part of the elaborate ventilating system are not in use, and have not been in use since the opening of the building. The vent fans in the roof space are in full use and are usually maintained in operation during the greater portion of the day, regardless of what the weather conditions may be outside. In the absence of the operation of the air supply fans a suction or minus pressure is established in the interior of the building, and cold, unfiltered air is drawn in through every orifice. The main source of interior supply would properly be the screening chamber leading to the blowers. On examining that it was found that there was no cheesecloth on the screen, but the opening leading to the chamber and thence into the buildings from the sidewalk was open, so you can imagine the result. On inquiry of the superintendent of the building I found that he was surprised at all times at the amount of dust that found its way into the building and thickly coated the priceless records of the city which are therein contained, and that it took twenty-eight cleaners to keep the building clean.

Now it is evident that ineptitude and stupidity of management are by no means confined to the Department of Education, but are to be found elsewhere. In other words, the agitation which has been directed particularly at the plants in the Department of Education might in fairness be widened to take in, let us say, the Department of Correction, and possibly some correction of conditions might result.

Mr. Williams: You are reaching a point where you are hitting the ventilating engineer in a tender spot. It is all right to talk about fine-spun theories of ventilation; but you had better see to the proper management of the operators if you want good ventilating results.

Some years ago I was in Massachusetts and it struck me as though they had a pretty good idea up there, and that is that they licensed all their engineers, made them go and pass an examination, and that gave the inspectors some control over the janitors in general. In long years of practice, not only as an engineer but as a contractor, a great many of my early mornings at five o'clock and six o'clock were spent in going out and correcting mistakes in the installation of the ventilating apparatus and observing the way it was operated; and my observations have led me to the conclusion that there are three classes of people that need more education in the line of ventilation than any other class of persons that I know. But I will start with the doctors first: I will come down to the teacher next and finally I will reach the janitor. He is usually appointed because he is good for nothing else. You may put all the fine-spun theories of ventilating into the machine or into the design of your apparatus, but if you do not have intelligent management of it you will never succeed.

Mr. Feldman: The public cannot be educated to employ intelligent janitors or firemen. I try to insist on my clients that they pay good wages.

I had a case during the recent cold spell. I had a heating and ventilating plant. It cost $30,000 and was working fine last year. I had a good engineer in charge and he did well. But the lady of the house wanted him to scrub the floors and do other things which he refused. This year she got another fellow who would scrub the floors and polish shoes, etc., but did not know how to manage the plant. The result was when a cold spell came he could not heat the building. There were a number of direct-indirect radiators there. When I looked over the plant I found several dampers to the stacks were closed. The fireman also closed up the main cold air damper so as to keep out the cold air. As soon as I had them all opened the house was heated all right. The fireman was discharged and replaced by a more competent one.

In connection with cooling, Mr. Kimball mentioned a hospital

where the cooling plant was abandoned. I take pride in having a plant that has been in successful operation for the past six years. I think the trouble in unsuccessful plants is in the design. Those who attempt to design for cooling usually design first for heating and then convert it into cooling; there is where the mistake is. The cold air should be introduced at such places where no drafts will be caused, but the exhaust registers should be placed where the people are sitting. A room should never be cooled more than 10 deg. lower than outdoors. There may be some physiological reason why it is comfortable with 80 deg. indoors, when it is 90 deg. outside.

One of the members of the firm for which I installed the plant referred to has commissioned me to cool his bedroom next summer in his country home. I am going to do it in connection with the ice machine for refrigeration. I am also designing an experimental plant for a large hospital in this city. The superintendent had an idea that the life of certain patients could be saved if kept in a cool room. The committee has accepted my plan and next summer it will be carried out.

Mr. Moore: I think we have the same trouble in Massachusetts in regard to janitors that you do in New York. I remember one of several cases. It was a fine school building, had a gravity system installed, also was in every way first-class. I had not had a chance to inspect it until about the middle of December. I received a complaint from the committee that the system was an entire failure, and that the air was bad.

Without seeing the committee I went to the school building about 11 o'clock, opening the door and going in. The air was foul, it was villainous. I found that every damper outlet was closed tight, the doors in the school room and the corridors were open; the door from the corridor down to the basement was open; the door leading into the cold room was open, but the cold air window or opening was not only fastened down with a bolt but it was nailed down. The air had been recirculated over and over. I called the janitor, told him to throw open every vent damper and open up his cold air inlet wide. He said, "Well, Mister, I have got nine pounds of steam on it now and I can hardly keep them warm." I said, "You give me three pounds of steam, that is all I want." He went around and threw everything open and adjusted things. When the session opened at one o'clock the principal came in and looked around and said,

"Why, what have you done here? I didn't think you had much time to do anything here, but it seems all right now." When the committee came they said, "Everything is all right." I said, "Call your janitor." Then I explained to them what I found. I said to them, "If you have any more trouble with this apparatus the only remedy is to get a new janitor"; and I think the committee acted on that principle, for I never heard a bit of complaint afterwards. They were getting 40 cu. ft. of air per minute and everything was all right.

Mr. Kimball: Mrs. Wise's statement of yesterday presented the extreme of conditions which we are meeting in this city at this time. It is bad enough to be in the position of private engineer and to design plants and then have to leave them to the mercy of the men whom they select, who, as has been stated, are very often men who cannot do anything else. I have been in contact with the situation in New York, and one of the problems in the schools was the difficulty of getting an observer. Our plan was to utilize the school nurse in registering details in connection with the health of the pupils, to utilize the standing of the pupils from records in that respect also; but when we wanted an observer to take the records as to the actual conditions in the room, and the request was made for that money, it was turned down by the Board of Estimate and Apportionment of New York. It has occurred to me it would not be amiss for our society to take a position in that matter and urge the adoption of the following resolution:

"Be it resolved that this society petition the Board of Education of New York City that arrangements be made whereby the supervision of janitors and engineers operating ventilation plants, the supervision of repairs, the supervision of plant operation and supervision of fuel supply, should be placed under the control of the department designing such plants; further, that it is most desirable that a limited sum be appropriated for the observation of ventilation tests, to be conducted in conjunction with the committee on schoolhouse ventilation of this society."

(After a long discussion, covering in part a reference of the question to the New York Chapter, and participated in by Messrs. Bishop, Barron, Bolton, Mackay, Wolfe, Whitten, Davis, Feldman, Chew, Kent and Macon, the resolution was passed.)

CCLXXVIII.

HEAT TRANSMISSION WITH INDIRECT RADIATION.

BY FRANK L. BUSEY.

The subject of the transmission of heat from steam or hot water to air through some form of radiating surface is ordinarily considered under the two divisions of direct and indirect radiation. The indirect system may be again divided into the two sub-divisions of gravity and forced circulation systems, depending on whether the air is caused to be drawn over the heating surface due to its rise in temperature or is caused to circulate by means of a fan. The present paper will be concerned principally with this latter system, that is, where the air is forced over indirect heaters of either wrought or cast iron, containing steam as the heating medium.

The author is greatly indebted to Mr. W. H. Carrier, chief engineer of the Buffalo Forge Company, as the originator of the theory of convection herein discussed, for the use of data from tests made under his direction, and for valuable advice and assistance in the preparation of the material here presented.

The theory of convection with forced circulation over indirect heaters has been thoroughly discussed, and the laws and constants for the same established in a paper presented at the December, 1911, meeting of the American Society of Mechanical Engineers,* so that a mathematical discussion of the subject need not be entered into at the present time. It will rather be the aim of this paper to elaborate on the laws therein established and to show their applicability to the various forms of indirect surface in common use, and give data from two additional sources tending still more completely to corroborate the theory.

TESTS ON BUFFALO STANDARD HEATERS WITH 5 LB. STEAM PRESSURE.

As explained in the paper above referred to, the results here presented are based on a series of ten tests made on a Buffalo

*Air Conditioning Apparatus, by W. H. Carrier and F. L. Busey.

indirect or fan system heater, consisting of eight sections each containing four rows of 1-in. wrought-iron pipe, making 126.6 sq. ft. of surface to each section, with a clear area of 10.263 sq.

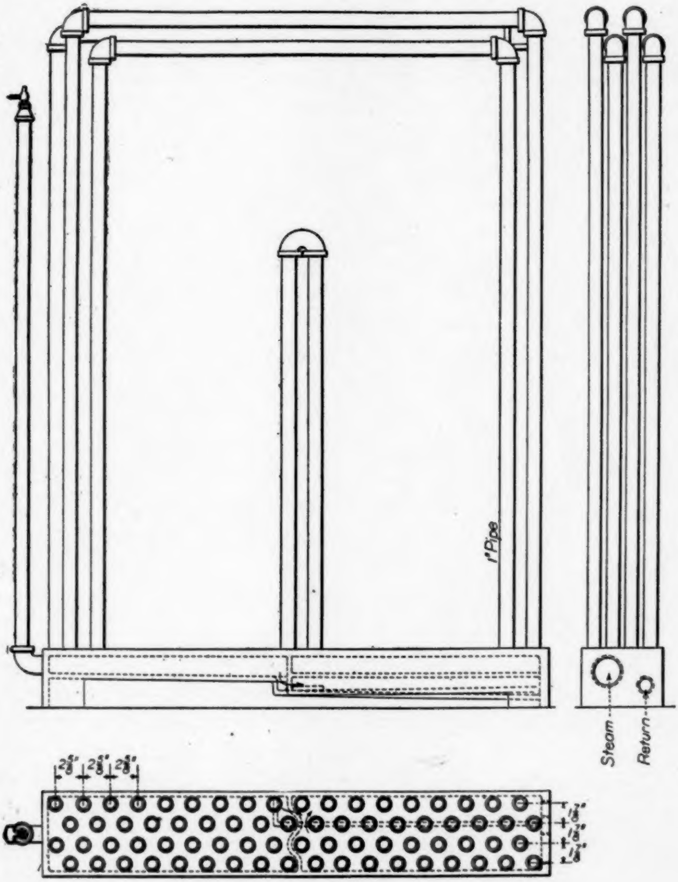


FIG. 1.—DETAIL OF HEATER CONSTRUCTION.

ft. Details of the arrangement of the pipes and their distribution in the cast-iron base are shown in Fig. 1. The air was drawn through the heater by a steel plate fan, the air measurements being taken at the nozzle outlet. The velocity of the air was measured by means of a pitot tube and hook gauge, the tempera-

tures being taken at the outlets with thermometers well protected from the effect of radiation. During the test continuous readings were taken with the pitot tube fixed in the centre of the orifice, these readings being then multiplied by the proper coefficient of discharge to obtain the corrected reading.

The pressure of the steam, as well as the speed of the fan engine, was kept constant throughout each test by two of the observers. The condensation from each section was weighed separately, and the temperatures carefully noted. Each section was provided with an air-vent, and thoroughly blown out for about one hour before starting the test and some steam was allowed to blow through during the entire test. A separator was placed in the steam line before the throttle, and a calorimeter was used to determine the quality of the steam as it entered the steam header. A slight degree of superheat was observed during each test, and the proper allowance made in the calculation of the total heat of the steam. The saturation temperature of the steam was also taken before and after each test to check the steam gauge, proper allowance being made for stem correction to the thermometer. Barometric readings were made during each test, and the steam pressure so regulated as to maintain an absolute pressure of 19.7 lb. on the heating coils. The steam gauge was calibrated by means of a dead-weight tester before and after each test, due allowance being made for the barometric reading taken at the time.

The principal data obtained from the ten tests are shown in Table 1, the first column for each test containing the uncorrected observations, the second column these same readings corrected to standard conditions of 70 deg. F. and 29.92 in barometer. The third column, as will be explained later, shows the results of a further correction of 8 per cent., to correct for a systematic error in the air measurement.

The values given under column 1 for each test show the actual test conditions after the following corrections had been made. Proper allowance was made for heat loss from the air by convection from the surface of the heater casing and fan housing, correction for this loss being added to the air temperature. Slight corrections were also made for condensation from such portions of the heater base and pipe connections as were exposed to the air of the room rather than to the air measured.

TABLE 1.—LOG OF OBSERVED AND CORRECTED RESULTS FROM TESTS ON BUFFALO STANDARD HEATER. STEAM PRESSURE 5-LB. GAUGE.

Test No.	1			2			3			4			5		
	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions,	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis
Revolutions Per Minute	80			120			160			200			240		
Barometer, In.	29.46			29.40			29.45			29.47			29.43		
Velocity through Clear Area. Ft. per Min.	335	276	254	453	375	345	594	499	459	738	626	576	960	805	741
Initial Temperature of Air	16.5	20.0		20.0	20.0		19.0	20.0		16.5	20.0		21.0	20.0	
Final Temperature of Air	174.4	183.4		170.4	176.4		162.5	167.6		156.5	160.8		155.0	157.1	
Temperature Rise	157.9	163.4		150.4	156.4		143.5	147.6		140.0	140.8		134.0	137.1	
Total Air per Min. — Cu. Ft.	3440	2830	2604	4650	3850	3542	6100	5110	4702	7570	6420	5906	9750	8260	7600
Total Air per Min. — Lb.	212	212	195	288	288	265	383	383	352	481	481	443	619	619	570
Condensation per Section, Lb. per ½-Hr. Run — 1st	58.5	59.2		66.4	68.3		82.2	83.8		97.0	97.8		104.7	108.2	
2d	45.3	46.2		55.0	56.8		69.7	71.5		83.5	84.5		91.4	94.3	
3d	34.6	35.4		43.4	45.0		57.5	59.0		69.2	70.1		76.7	79.2	
4th	28.6	29.4		36.0	37.4		49.1	50.5		60.1	61.0		66.3	68.6	
5th	24.2	25.0		30.9	32.2		42.9	44.1		53.1	54.0		60.6	62.9	
6th	17.3	18.0		23.3	24.5		33.8	35.0		42.4	43.2		49.9	51.9	
7th	14.8	15.6		19.6	20.7		28.5	29.6		36.1	36.9		43.2	45.0	
8th	12.2	12.7		16.4	17.3		24.1	25.0		30.8	31.4		37.6	39.1	
Total Condensation — ½ Hr.		241.5			302.2			398.5			478.9			549.2	
Total Condensation — 1 Hr.		483.0			604.4			797.0			957.8			1098.4	
B.t.u. Delivered per Lb. of Condensation		977.0			979.4			982.3			979.0			976.1	
B.t.u. per Sq. Ft. Heater per Hr. from the Steam		466.0			583.0			773.0			926.0			1058.0	
B.t.u. per Sq. Ft. per Hr. absorbed by the Air		496.0	456		644.0	592		808.0	743		967.0	890		1214.0	1117.0

This loss was found to amount to 78.4 B.t.u. per hour per degree difference between the steam and room temperature. A further correction was also required to make allowance for the fact that the condensation left the heater at practically steam

TABLE 1 (*Continued*).—LOG OF OBSERVED AND CORRECTED RESULTS FROM TESTS ON BUFFALO STANDARD HEATER. STEAM PRESSURE 5-LB. GAUGE.

Test No.	6			7			8			9			10		
	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per Cent Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8 Per cent Correction Basis
Revolutions Per Minute	280			320			360			360			400		
Barometer, In.	29.40			29.43			29.43			29.43			29.40		
Velocity through Clear Area, Ft. per Min.	1067	911	838	1199	1027	945	1315	1135	1044	1345	1165	1072	1401	1286.0	1183
Initial Temperature of Air	20.5	20.0		21.5	20.0		20.6	20.0		19.5	20.0		19.8	20.0	
Final Temperature of Air	150.1	152.0		145.6	149.8		142.6	143.5		143.6	145.4		142.6	143.9	
Temperature Rise	129.6	132.0		127.1	129.8		122.0	123.5		124.1	125.4		122.8	123.9	
Total Air per Min. — Cu. Ft.	10050	9350	8602	12300	10520	9679	13500	11650	10720	13800	11950	10995	15300	13200.0	12145
Total Air per Min. — Lb.	701	701	645	789	789	726	873	873	803	895	895	823	989	989	910
Condensation per Section, Lb. per ½-Hr. Run — 1st	112.2	115.0		130.6	134.5		140.2	143.1		136.2	139.1		145.7	149.2	
2d	107.0	110.0		114.1	117.8		113.0	116.0		123.6	126.7		135.1	138.6	
3d	87.4	90.0		97.6	101.0		109.6	112.8		107.1	109.8		115.7	118.8	
4th	76.9	79.3		87.6	90.6		99.1	102.0		96.2	98.6		103.8	106.4	
5th	68.6	70.9		78.1	80.8		89.5	92.2		86.5	88.7		89.9	92.5	
6th	57.4	59.4		64.4	66.7		74.1	76.4		72.7	74.7		80.1	82.5	
7th	50.2	50.0		57.5	59.7		66.9	69.0		66.1	68.0		73.4	75.6	
8th	43.6	45.2		50.7	52.5		59.9	61.8		58.6	60.2		64.1	66.0	
Total Condensation — ½ Hr.		621.8			703.6			773.3			765.8			829.6	
Total Condensation — 1 Hr.		1243.6			1407.2			1546.6			1531.6			1659.2	
B.t.u. Delivered per Lb. of Condensation		977.1			968.9			972.2			970.3			975.1	
B.t.u. per Sq. Ft. Heater per Hr. from the Steam		1200.0			1345.0			1483.0			1470.0			1595.0	
B.t.u. per Sq. Ft. per Hr. absorbed by the Air		1322.0	1216		1466.0	1349		1546.0	1422		1606	1477		1753.0	1613

temperature, and a portion would flash into steam upon exposure to the atmosphere. After careful tests it was decided to add 1.5 per cent. to the weight of condensation to cover this loss, as well as 1½ lb. per half hour to cover the average loss due to evapora-

tion from the tanks containing the condensation. A final correction was then made to reduce all the tests to a standard of 20 deg. for the temperature of the entering air.

The values plotted in Fig. 2 are taken from Table 1, the three lines representing the three conditions for each test. The velocity through the clear area was computed from the air measure-

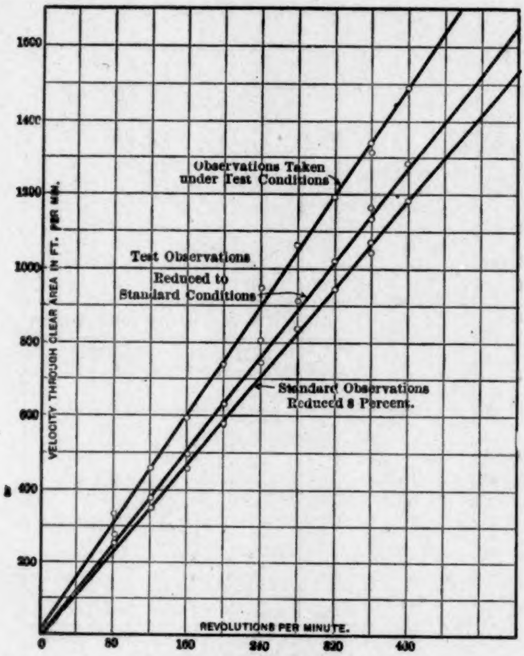


FIG. 2.—RELATION OF FAN SPEED TO VELOCITY OF AIR THROUGH HEATER.

ments, and it will be noticed that, with the exception of the tests at 80 and 240 r.p.m., the velocity and speed correspond very closely.

An explanation of the 8 per cent correction to the velocity and air measurements is shown by the two curves in Fig. 3. These curves are plotted from the values given in column 2 of these tests in Table 1, which give the air velocities based on actual air measurements reduced to standard conditions. As indicated, the upper curve gives the B.t.u as computed from the corrected air

measurements, while the lower curve gives the rate of transmission as determined from the condensation. It was found that these two curves show a uniform discrepancy of approximately 8 per cent. As both the temperature and condensation measurements were made with considerable care, and since the percentage of error is substantially uniform at all velocities, it is evident

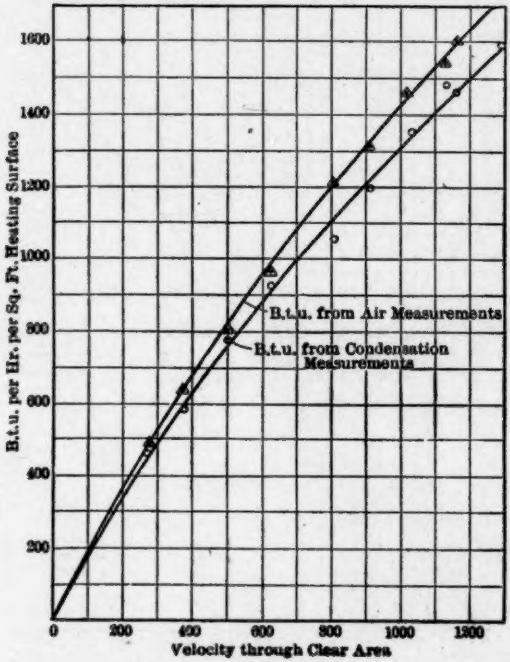


Fig. 3.—Effect of Velocity upon Rate of Transmission from Original Air Measurements.

that a systematic error of 8 per cent was made in the measurement of the air volume. Accordingly both the rate of transmission from the air measurements and the corresponding velocities have been reduced 8 per cent.

The curve in Fig. 4 has been plotted from these corrected values and from the condensation. These show a remarkably close agreement of both values, and establish the true form of the curve.

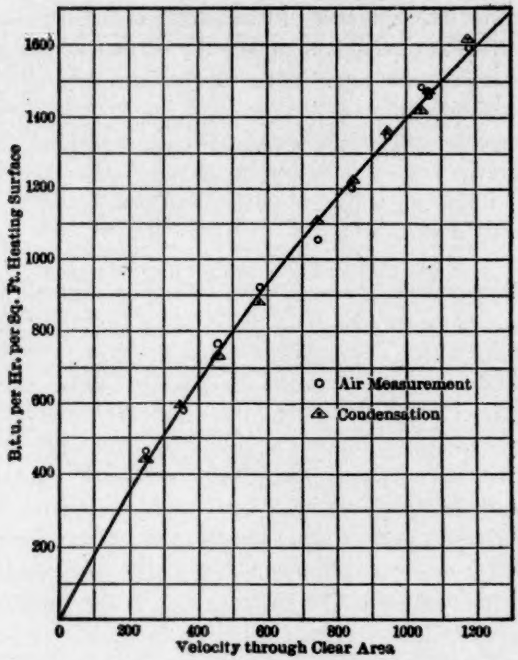


FIG. 4.—COMBINED CURVE SHOWING RATE OF TRANSMISSION FROM CONDENSATION AND AIR MEASUREMENTS. CORRECTED FOR 8 PER CENT ERROR IN AIR MEASUREMENTS.

The coefficient of transmission for the different sections at various velocities has been carefully considered in the paper on air conditioning apparatus already referred to, so that the formula

$$K = \cfrac{1}{R + \cfrac{B}{C_p W_0 V_0}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

as well as the values determined for the constant R and B may be accepted as therein given. In the above formula,

K = the rate of transmission in B.t.u. per sq. ft. per hour per degree difference in temperature between the steam and air.

R = the total resistance of the surface film of the steam, of the conducting wall and of the surface film of the convecting medium.

B = a constant.

C_p = specific heat of the air or convecting medium.

W_0 and V_0 represent the corresponding density and velocity of the air at the absolute base temperature θ or 70 deg. Fahr.

From this combined curve, shown in Fig. 4, as well as from a set of curves giving the B.t.u. transmitted from each section, the heat transmission at any velocity may be determined. It was from this set of curves that the values given in column 2 of Table 2 were obtained. Values exhibited here are taken at a velocity of 1,000 ft. per minute through the clear area, and while comparisons are given here for only one velocity, it should be understood that the same comparisons have been made at other velocities. Column 3 gives the temperature rise in each consecutive section, as computed from the experimental rate of transmission given in column 2, this relationship being expressed by the formula

$$\theta_2 - \theta_1 = \frac{H'S}{60\, C_p A\, W_0 V_0} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where H' = B.t.u. per hour per sq. ft.

S = Surface of heater in sq. ft.

A = Clear area through heater in sq. ft.

θ_1 = Absolute temperature of air entering heater.

θ_2 = Absolute temperature of air leaving heater.

θ_s = Absolute temperature of the steam.

The fourth column gives the computed temperature leaving the consecutive sections. From column 4, columns 5 and 6 are computed. Column 7 gives the ratio of the initial to the final temperature difference between the steam and air, for each consecutive section. From this comparison it will be seen that this ratio $(\theta_s - \theta_1) \div (\theta_s - \theta_2)$ is approximately constant in all sections, for any one velocity, regardless of the variation in the entering temperature. If the rate of transmission per degree difference in temperature between steam and air was absolutely

Velocity Through Clear Area 1000 Ft. per Min. $\theta_s = 227$ Deg. Fahr. $\theta_1 = 20$ Deg. Fahr.

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of Section	B.t.u. per Sq. Ft. per Section	Temperature Rise per Section	Temperature of Air Leaving Section	Average Absolute Temperature in Each Section θ_A	Final Temperature Difference $\theta_s - \theta_2$	Ratio of Leaving to Entering Temperature Difference $\frac{\theta_s - \theta_2}{\theta_s - \theta_1}$	$\text{Log}\,\frac{\theta_s - \theta_1}{\theta_s - \theta_2}$	Absolute Film Temperature θ'	R Calculated from Film Temperature	K Calculated from Formula	K from Test	R Calculated from Test
1	2092	23.75	43.75	491.88	183.25	0.88528	0.05292	596.60	0.04267	10.72	10.74	0.04250
2	1838	20.88	64.63	535.07	162.37	0.88605	0.05254	615.78	0.04404	10.56	10.64	0.04333
3	1614	18.32	82.95	552.10	144.05	0.88725	0.05195	623.77	0.04461	10.55	10.55	0.04414
4	1418	16.10	99.05	567.10	127.95	0.88830	0.05144	630.79	0.04611	10.44	10.52	0.04438
5	1249	14.18	113.23	580.32	113.77	0.88910	0.05105	636.99	0.04555	10.39	10.36	0.04587
6	1104	12.53	125.76	592.03	101.24	0.88920	0.05100	642.48	0.04595	10.35	10.38	0.04565
7	981	11.14	136.90	602.47	90.10	0.89000	0.05061	647.37	0.04630	10.32	10.27	0.04668
8	878	9.97	146.87	611.86	80.13	0.88935	0.05093	651.77	0.04661	10.29	10.33	0.04615

Table 2.—Showing the Film Resistance R to Vary as the Absolute Film Temperature.

constant at any one velocity, it could be shown that the ratio of $(\theta_s - \theta_1) \div (\theta_s - \theta_2)$ for any section as well as log $[(\theta_s - \theta_1) \div (\theta_s - \theta_2)]$ would also be absolutely constant, and conversely.

It will be seen, however, from column 8 that the log decreases regularly from the first to the last section. Column 9 gives the absolute film temperature (θ') as calculated from formula

$$\theta' = \theta_s - RK(\theta_s - \theta) \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

From this it will be seen that log $[(\theta_s - \theta_1) \div (\theta_s - \theta_2)]$ while varying inversely with the absolute film temperature, varies at a much less rapid rate. Column 12 gives the values of *K*, the factor of transmission, as calculated from the values in column 8. From the experimental constants, determined in the manner to be described later, we are able to calculate the variations in the value of *R* (according to formula (1)), as shown in column 13, from the values of *K* as determined from the tests. In column 10 the variations in *R* have been calculated on the assumption that the film resistance is directly proportional to the absolute film temperature. The substantial agreement of the values thus calculated, with the values of *R* in column 13 as calculated from the tests is clearly shown. In column 11 the value of *K* has been calculated from the film temperature. The close agreement of these values of *K* as calculated from the

formula may be shown by comparison with the values of K as determined from tests in column 12.

It is of especial interest to note the relation between the absolute film temperature and the values of K and R as shown in this table. The film temperature increases from the first to the eighth section, the total increase being 8½ per cent. The value of R, the resistance to the passage of heat to the air, increases as the film temperature increases and at approximately the same rate. It will be shown later for other tests that while these values do not always increase at exactly the same rate, the increase appears to be approximately proportional for the cases examined. It will be noticed from Table 2 that while the values of θ' and R increase, the value of K, the coefficient of transmission, decreases, the rate being 3.8 per cent. The same substantial agreement between the values of θ' and R having been found at other velocities warrants the assertion that the value of R as the resistance in the air surface film varies approximately as the calculated absolute film temperature. Inasmuch as it has been proved that the resistance of the steam film and conducting wall is very slight compared to the resistance of the air surface film, R may be assumed as representing the entire resistance to the transmission of heat.

For eight sections of heater with the velocity of the air through the clear area of the heater, measured at 70 deg. F., at 1,000 ft. per minute, we find a mean absolute film temperature of approximately 625 deg. Therefore we have calculated the value of R_0 and all values of K_0 at different velocities for this assumed standard of film temperature. Having calculated the average values of K for 8 sections of heater and different velocities as described in the preceding paragraph, we may determine the value of K_0 for a film temperature of 625 deg. from a formula given in the paper referred to.

In Table 3 are shown values determined in the various steps employed in calculating the coefficients of heat transmission at various velocities. As already explained, K is the rate of transmission calculated for the actual and K_0 for the mean absolute film temperature. These values for K_0 as calculated from the tests are shown in column 12. The values of X in column 10 were calculated by means of an equation also given in the A. S. M. E. paper previously referred to.

1	2	3	4	5	6	7	8	9	10	11	12	13
V	$\frac{1}{V}$	$\frac{H}{S}$ = B.t.u. per Sq. Ft.	$\theta_s-\theta_1 = \frac{s\times\frac{H}{S}}{\frac{A\times 60\times V}{55.23\times S}}$	$\theta_s-\theta_2$	K	$\frac{1}{K}$	$(\theta_s-\theta)m$	$K(\theta_s-\theta)m$	X	$\frac{1}{K_0}=\frac{1}{K}-X$	K_0 from Test	K_0 Calculated from Formula
200	0.0050	355	160.8	46.2	3.316	0.3015	107.0	355	0.00331	0.29819	3.354	3.356
300	0.00333	518	156.5	50.5	4.674	0.2140	111.0	520	0.00279	0.21121	4.735	4.689
400	0.0025	667	151.1	55.9	5.788	0.1730	115.4	667	0.002295	0.17071	5.858	5.838
500	0.0020	805	145.9	61.1	6.743	0.1480	119.6	806	0.001815	0.14619	6.841	6.845
600	0.001667	936	141.3	65.7	7.614	0.1310	123.0	938	0.00143	0.12957	7.718	7.746
700	0.00143	1060	137.2	69.8	8.412	0.1190	126.5	1067	0.001012	0.11799	8.476	8.540
800	0.00125	1178	133.4	73.6	9.146	0.1093	129.0	1180	0.000639	0.10866	9.204	9.251
900	0.00111	1290	129.9	77.2	9.823	0.1018	131.3	1290	0.000279	0.10152	9.850	9.896
1000	0.00100	1398	126.7	80.3	10.465	0.0956	133.5	1397	−0.0000585	0.09566	10.455	10.490
1100	0.000909	1500	123.5	83.5	11.040	0.0905	136.0	1507	−0.000418	0.09092	11.000	10.920
1200	0.000833	1599	120.8	86.3	11.610	0.0861	137.7	1600	−0.000936	0.08704	11.490	11.400

TABLE 3.—COEFFICIENTS OF HEAT TRANSMISSION AT VARIOUS VELOCITIES.

We now have the rates of transmission for different velocities corrected to a standard absolute film temperature of 625 deg. The plot of these values for different velocities as determined from the test curve, Fig. 4, is shown in Fig. 5. It will be noticed from an inspection of Fig. 5 that these points lie, with remarkable accuracy, in a straight line, showing the agreement of the

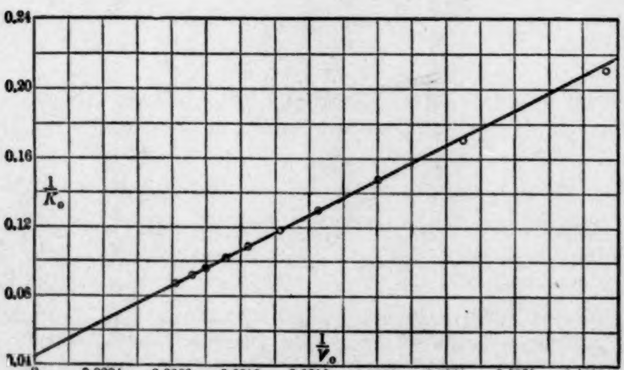


FIG. 5.—CURVE SHOWING DERIVATION OF CONSTANTS IN RATIONAL CONVECTION FORMULA.

test results with the rational formula, (1). Column 13, Table 3, shows the value of K_0 calculated from the formula, which may be compared with the values of K_0 calculated from the tests and shown in column 12. It will be noticed that this variation ranged from 0.2 to 0.8 of 1 per cent.

Fig. 6 gives the values of K_0 for different velocities, the curve being plotted from the formula and the points shown being the

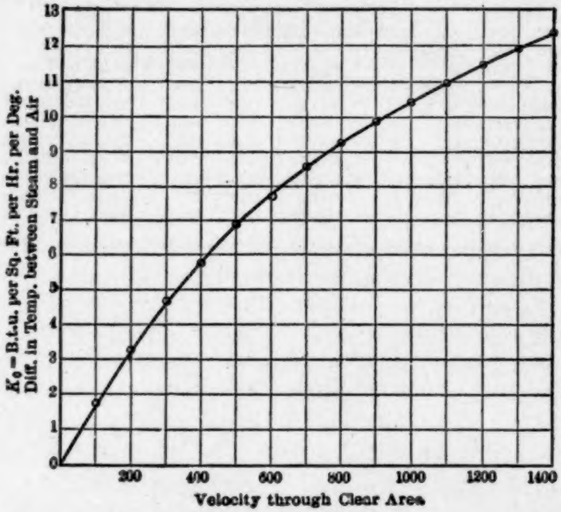


FIG. 6.—RATE OF HEAT TRANSMISSION FOR VARIOUS VELOCITIES. VALUES OF K_0 FROM TESTS CORRECTED TO ABSOLUTE FILM TEMPERATURE OF 625 DEG. FAHR.

values determined directly from the test. The remarkably close agreement of the points with the line will be noticed from an inspection of the chart.

To obtain a full realization of the extreme accuracy of the formulas and of the results calculated by means of them it is necessary to make a comparative study of the actual test results as shown in Table 2 with calculated results in Table 4. For convenience these values are reproduced in Table 5, in which the comparison should be made between the corresponding columns.

VELOCITY THROUGH CLEAR AREA 1000 FT. PER MIN. $\theta_s = 227$ DEG. FAHR. $\theta_1 = 20$ DEG. FAHR.

1	2	3	4	5	6	7	8	9	10	11	12
Number of Section	f	Log of Approximate $\frac{\theta_s - \theta_1}{\theta_s - \theta_2}$	K_0 X from Curve	$\frac{\text{Log}\frac{\theta_s - \theta_1}{\theta_s - \theta_2}}{1 + K_0 X}$	$\frac{\theta_s - \theta_1}{\theta_s - \theta_2}$ Corrected	$\theta_s - \theta_2$	Final Temperature	Total Temperature Rise	Average B.t.u. per Sq. Ft., Total	Temperature Increment in Section	Average B.t.u. per Sq. Ft. per Section
1	12.335	0.05167	−0.0224	0.05285	1.130	183.20	43.80	23.80	2096.4	23.80	2096.5
2	24.67	0.10334	−0.0188	0.10534	1.2745	162.42	64.58	44.58	1963.5	20.78	1830.4
3	37.005	0.15501	−0.0152	0.15739	1.4368	144.07	82.93	62.93	1840 8	18.35	1616.3
4	49.34	0.20668	−0.0115	0.20909	1.6174	127.98	99.02	79.02	1740.0	16.09	1417.2
5	61.675	0.25835	−0.0084	0.26032	1.8220	113.61	113.39	93.39	1645.5	14.37	1265.8
6	74.01	0.31002	−0.00533	0.31168	2.0497	101.00	126.00	106.00	1556.0	12.61	1110.8
7	86.345	0.36169	−0.00225	0.36250	2.304	89.85	137.15	117.15	1474.2	11.15	982.2
8	98.68	0.41336	+0.00084	0.41301	2.5883	79.98	147.02	127.02	1398.5	9.87	869.4

TABLE 4.—CALCULATIONS FOR CORRECT VALUES OF FINAL TEMPERATURE AND HEAT TRANSMISSION.

VELOCITY THROUGH CLEAR AREA 1000 FT. PER MIN. $\theta_s = 227$ AND $\theta_1 = 20$ DEG. FAHR.

	TEST RESULTS FROM TABLE 2				CALCULATED RESULTS FROM TABLE 4			
	1	2	3	4	5	6	7	8
Number of Section	Average B.t.u. per Sq. Ft. per Section	Temperature Rise per Section	Temperature of Air Leaving Section	Final Temperature Difference $(\theta_s - \theta_2)$	Average B.t.u. per Sq. Ft. per Section	Temperature Rise per Section	Temperature of Air Leaving Section	Final Temperature Difference $(\theta_s - \theta_2)$
1	2092	23.75	43.75	183.25	2096.5	23.80	43.80	183.2
2	1838	20.88	64.63	162.37	1830.4	20.78	64.58	162.4
3	1614	18.32	82.95	144.05	1616.3	18.35	82.93	144.07
4	1418	16.10	99.05	127.95	1417.2	16.09	99.02	127.98
5	1249	14.18	113.23	113.77	1265.8	14.37	113.39	113.61
6	1104	12.53	125.76	101.24	1110.8	12.61	126.00	101.00
7	981	11.14	136.90	90.10	982.2	11.15	137.15	89.85
8	878	9.97	146.87	80.13	869.4	9.87	147.02	79.98

TABLE 5.—COMPARISON OF TEST AND CALCULATED RESULTS.

TESTS ON BUFFALO STANDARD HEATER WITH 50-LB. STEAM PRESSURE.

To study the effect of higher steam pressure on the rate of transmission as well as the relationship between the film resist-

TABLE 6.—LOG OF OBSERVED AND CORRECTED RESULTS FROM TESTS ON EIGHT SECTIONS BUFFALO STANDARD WROUGHT IRON PIPE HEATERS;—STEAM PRESSURE, 50 LB. GAUGE

TEST NUMBER	1			2			3			4			5		
	Test Conditions	Reduced to Standard Conditions	Reduced to 8% Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8% Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8% Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8% Correction Basis	Test Conditions	Reduced to Standard Conditions	Reduced to 8% Correction Basis
Rev per Min. of Fan	80			80			120			160			200		
Barometer—Inches	29.44			29.39			29.47			29.39			29.47		
Velocity Through Clear Area—Ft. per Min.	368	279	257	309	234	215	419	322	296	602	467	430	708	555	511
Initial Air Temp.	33.1	30		24.4	30		29.0	30		27.6	30		29.4	30	
Final Air Temp.	228	237.6		225.5	247.0		220	231.8		211	220.5		207	213.3	
Temperature Rise	194.9	207.6		201.1	217.0		191	201.8		183.4	190.5		177.6	183.3	
Total Air per Minute Cu. Ft.	3780	2863	2634	3170	2400	2208	4300	3300	3036	6180	4790	4407	7270	5700	5244
Total Air per Minute Lbs.	215	215	198	180	180	166	247	247	227	358	358	329	427	427	393
Total Condensation ½ Hour	264.5			292			376.4			502.9			570.6		
Total Condensation 1 Hour	529	572.1		584	612.3		752.8	790.3		1005.8	1080.5		1141.2	1236.5	
B.t.u. per Sq. Ft. Heater per Hour from the Steam		515			551			711			972			1112	
B.t.u. per Sq. Ft. per Hour Absorbed by the Air		638	547		559	514		713	656		975	897		1119	1030

TEST NUMBER	6			7			8			9			10		
Rev. per Min. of Fan	240			240			280			280			320		
Barometer—Inches	29.44			29.47			29.44			29.41			29.41		
Velocity Through Clear Area—Ft. per Min.	896	704	648	870	686	631	1041	823	757	1033	818	753	1171	950	874
Initial Air Temp.	32.5	30		29.8	30		31.8	30		29.5	30		28.4	30	
Final Air Temp.	204.1	205.8		202.6	207.1		198.2	199.8		198.1	202.1		192.2	196.7	
Temperature Rise	171.6	175.8		172.8	177.1		166.4	169.8		168.6	172.1		163.8	166.7	
Total Air per Minute Cu. Ft.	9200	7230	6652	8930	7040	6477	10680	8450	7774	10600	8400	7729	12020	9750	8970
Total Air per Minute Lbs.	541	541	498	526	526	484	635	635	584	629	629	579	730	730	672
Total Condensation ½ Hour	675.9			670.4			751.7			711.6			805.1		
Total Condensation 1 Hour	1351.8	1485.5		1340.8	1459		1503.4	1649.5		1423.2	1547		1610.2	1746	
B.t.u. per Sq. Ft. Heater per Hour from the Steam		1339			1312			1484			1391			1570	1601
B.t.u. per Sq. Ft. per Hour Absorbed by the Air		1360	1251		1332	1225		1542	1419		1548	1424		1740	

TABLE 7.—SHOWING THE FILM RESISTANCE TO VARY AS THE ABSOLUTE FILM TEMPERATURE; EIGHT SECTIONS OF BUFFALO STANDARD HEATER; STEAM PRESSURE, 50 LB. GAUGE; θ_1 = 30 DEG. FAHR.

1	2	3	4	5	6	7	8	9	10	11	12	13
V	B.t.u. per Sq. Ft. per Hour from Curve—Fig. 8	Temperature Rise	Final Temperature	Final Temperature Difference	Mean Temperature Difference—Steam and Air	Mean Absolute Film Temperature	Film Resistance R	K	$\frac{1}{K}$	X from Curve (Fig. 9)	$\frac{1}{K_o}=\frac{1}{K}-X$	K_o
200	459	208.4	238.4	59.3	138.2	733.5	.0525	3.322	.3011	.00810	.29300	3.413
300	661	200.1	230.1	67.6	145.3	723.3	.0517	4.549	.2198	.00730	.21250	4.706
400	850	193.0	223.0	74.7	151.1	714.0	.0510	5.626	.1778	.00667	.17113	5.838
500	1026	186.4	216.4	81.3	156.3	705.7	.0505	6.565	.1523	.00605	.14625	6.839
600	1190	180.1	211.1	86.6	159.5	697.8	.0499	7.461	.1340	.00552	.12848	7.784
700	1343	174.2	204.2	93.5	165.5	691.5	.0495	8.064	.1240	.00495	.11905	8.403
800	1492	169.4	199.4	98.3	169.0	684.2	.0489	8.829	.1133	.00447	.10883	9.190
900	1632	164.7	194.7	103.0	172.3	678.4	.0485	9.472	.1056	.00402	.10158	9.846
1000	1765	160.3	190.3	107.4	175.4	672.1	.0481	10.063	.0994	.00360	.09580	10.440
1100	1895	156.4	186.4	111.3	178.1	666.7	.0477	10.640	.0940	.00325	.09075	11.020

ance and film temperature at higher pressures and temperatures, use has been made of a series of ten tests with a steam pressure of 50 lb. on the coils. These tests were made at the same time as those previously described, on the same apparatus and by the

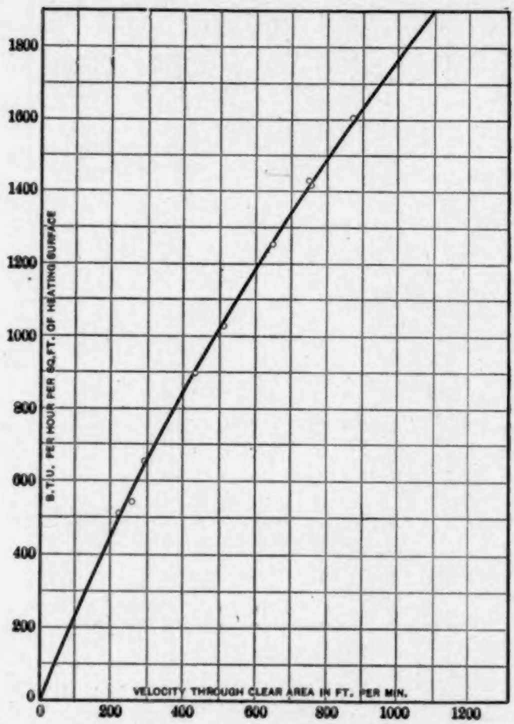


FIG. 8.—RATE OF TRANSMISSION FROM BUFFALO HEATER. STEAM PRESSURE 50 LB.

same observers, but the results were not fully worked up until the present investigation was undertaken.

The log of the observed and corrected results will be found in Table 6, in which the same corrections have been made as in Table 1. The weight of the condensation from each section was obtained as in the first series of tests, but are not given here, as only the total condensation was used in the present calculations. The same discrepancy of 8 per cent in the air velocity was assumed to exist, as the tests were all run under identical condi-

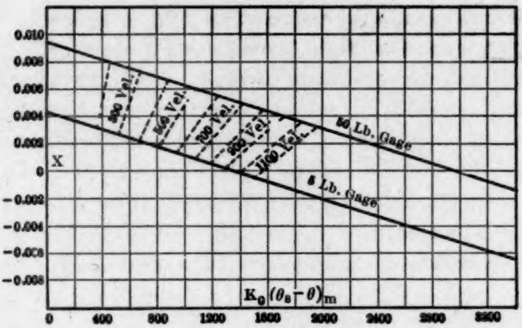


FIG. 9.—RELATION BETWEEN K_o $(\theta_s-\theta_m)$ AND X AT DIFFERENT STEAM PRESSURES.

tions, and corrections have been made similar to those described for the first series of tests. These corrected values are given in Table 6.

The curve in Fig. 8 is plotted from the corrected B.t.u. values given in Table 6. From this curve were taken the values given in column 2 of Table 7, showing the B.t.u. per sq. ft. per hour at the different velocities. The method of calculating the results given in Table 7 are the same as already explained, except that the values of X were taken directly from Fig. 9 in order to simplify the calculations. This is the correction made to reduce K

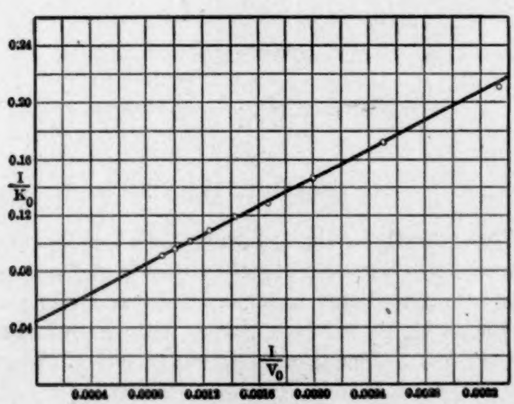


FIG. 10.—CURVE SHOWING DERIVATION OF CONSTANTS IN RATIONAL FORMULA FOR BUFFALO HEATER. STEAM PRESSURE 50 LB.

to the standard film temperature of 625 deg. absolute. The two lines in Fig. 9 are for steam pressures of 5 and 50 lb. pressure, the dotted lines being drawn through points corresponding to the values of X for velocities and steam pressure indicated. Columns 7 and 8 show the film temperature and resistance as calculated from the tests. Column 9 gives the values of K, the coefficient of transmission computed for the corresponding velocities and film temperatures. The values of K_0 in column 13 are reduced to a standard absolute film temperature of 625 deg.

In Fig. 10 the values of $\frac{1}{K_0}$ are plotted against $\frac{1}{V_0}$ the same as was done in Fig. 5 for the tests at 5 lb. pressure. Comparison of these two charts will disclose the fact that they are identical, so that the formula for 50 lb. steam pressure will also be the formula for 5-lb. pressure, or

$$K_0 = \frac{1}{.0447 + \frac{50.66}{V_0}}$$

where $\theta' = 625$ degrees absolute.

$$\text{and } K = \frac{1}{\frac{.0447\ \theta'}{625} + \frac{50.66}{V_0}}$$

APPLICATION OF THE THEORY TO TESTS ON VENTO HEATERS.

To further investigate the applicability of this theory, a study was made of the tables on Vento cast-iron heaters, as published by the American Radiator Company. These tables were computed by Mr. L. C. Soule in accordance with the formula of Mr. L. A. Cherry and the uniformity of the results is shown by the curve in Fig. 11. Mr. Soule described his method of making the tests and calculating the results in a paper read before this Society at the June meeting, 1910.

While a slight discrepancy appears to exist in the temperature rise given for low velocities and for a small number of sections, this is probably due to the effect of radiation from the end sections. Inasmuch as the condensation was not weighed separately for each section, it would be difficult to determine this effect,

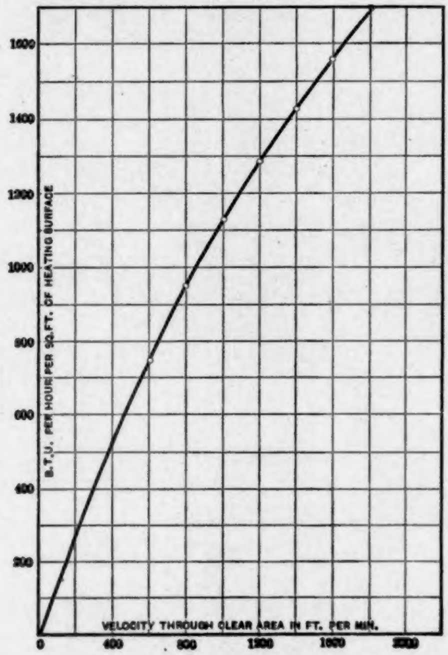


FIG. 11.—RATE OF TRANSMISSION FROM VENTO HEATER.

while in the tests on pipe heaters previously described this loss was provided for.

While the tables for different heaters and conditions were examined, only one case will be here considered. The results here deduced are based on the temperature rise given for six regular sections, 5 in. centres of loops, steam pressure 5-lb. gauge, air entering at 40 deg. F. The B.t.u. per hour per sq. ft. at different velocities were calculated from these temperatures, and the values plotted, as shown in Fig. 11. From this curve the B.t.u. as used in the calculations were taken, and as shown in Table 8

TABLE 8.—SHOWING THE FILM RESISTANCE R TO VARY AS THE ABSOLUTE FILM TEMPERATURE; SIX SECTIONS VENTO REGULAR CAST IRON HEATER; FIVE INCH CENTERS; STEAM PRESSURE 5 LB. GAGE; θ_i = 40 DEG. FAHR.

1	2	3	4	5	6	7	8	9	10	11	12	13
V	B.t.u. per Sq. Ft. per Hour from Curve—Fig. 11	Temperature Rise	Final Temperature	Final Temperature Difference	Mean Temperature Difference—Steam and Air	Mean Absolute Film Temperature	Film Resistance R	K	$\frac{1}{K}$	X from Curve	$\frac{1}{K'} = \frac{1}{K} - X$	K'
200	282	140.5	180.5	46.5	100.9	672.6	.0511	2.795	.3578	+.00350	.3543	2.819
300	411	136.5	176.5	50.5	104.1	666.1	.0507	3.948	.2533	+.00307	.2502	3.990
400	530	132.0	172.0	55.0	107.8	660.4	.0503	4.917	.2032	+.00272	.2005	4.990
500	645	128.5	168.5	58.5	110.5	654.8	.0497	5.837	.1713	+.00235	.1689	5.922
600	752	124.9	164.9	61.1	111.6	649.8	.0494	6.738	.1484	+.00200	.1464	6.825
800	950	118.3	158.3	68.7	118.0	640.6	.04875	8.051	.1242	+.00151	.1228	8.145
1000	1125	112.1	152.1	74.9	122.4	632.6	.0480	9.191	.1088	+.00080	.1080	9.255
1200	1285	106.7	146.7	80.3	126.5	626.0	.0476	10.160	.0984	+.00030	.0981	10.200
1400	1428	101.6	141.6	85.4	129.5	619.8	.0471	11.030	.0907	—.00017	.0908	11.050
1600	1560	97.2	137.2	89.8	132.4	614.3	.0467	11.780	.0849	—.00055	.0855	11.700
1800	1688	93.4	133.4	93.6	134.9	609.0	.0463	12.505	.0800	—.00098	.0810	12.350

the same method of computation was followed as already described for Table 7.

Values of $\frac{1}{K_0}$ from Table 8 are plotted to corresponding values of $\frac{1}{V_0}$ in Fig. 12, as shown by the upper of the two lines

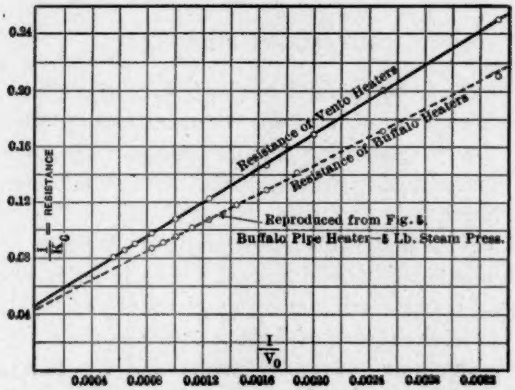


FIG. 12.—CURVE SHOWING DERIVATION OF CONSTANTS IN RATIONAL FORMULA FOR VENTO HEATERS.

and values for use in equations (1) obtained. The equation for the Vento tests will then be

$$K_0 = \frac{1}{0.047 + \frac{61.00}{V_0}}$$

where $\theta^1 = 625$ degrees absolute. As a matter of comparison the dotted line shown is a reproduction of the line obtained for Buffalo pipe heaters.

It would be expected that these two lines should intersect at the point where they cross the vertical axis giving a value of the film resistance which theoretically should be identical in all cases. The reason why they do not so intersect is probably due to the

fact that in the surface estimate of the Buffalo heater, sufficient allowance was not made for the increase of surface due to the area of the elbow being greater than the equivalent length of pipe. In the Vento heater, due to the intricate form of the surface, which is difficult to measure, it is possible that they were slightly overestimated. As regards the difference in slope of the two lines, this is to be expected, as the ratio between rated and effective velocity in one type of heater does not correspond to the similar ratio for the other.

COMPARISON OF RESULTS.

In Table 9 will be found a comparison of the values obtained from the three series of tests, for the mean absolute film temperature and the corresponding film resistance. The coefficient of transmission reduced to the standard absolute film temperature of 625 deg., absolute is also given for each series. A study of the values of θ'_m and R will disclose the fact that the variation in these two is approximately constant for each series, the relative percentage of total variation being given at the bottom of the table. That is, the results of these tests would appear to substantiate the assumption previously made, that the film resistance varies approximately directly as the mean absolute film temperature.

The values of K_0 for Buffalo heaters is practically constant for corresponding velocities, but for the Vento heaters the value is shown to be lower, doubtless due to the lower coefficient of friction. It should be noted, however, that for the same frictional loss there is practically no difference in the rate of transmission.

PRACTICAL APPLICATIONS.

Figs. 13 and 14 show the practical value of the formulas herein presented in their application to indirect heaters, either of wrought-iron pipe or of cast iron. The lower edge of the chart is divided into two scales, the upper being for standard Buffalo wrought-iron pipe heaters, with a value for f of 12.335 for each section, while the lower scale may be used for special pipe heaters for which the ratio f may be determined. The scale at the top of the chart has been drawn for the regular Vento cast-iron

TABLE 9.—COMPARISON OF THE VALUES OF θ'_m, R, K AND K_o.

BUFFALO STANDARD W. I. PIPE HEATERS

Velocity	Steam Press. 5 lb. Mean Absolute Film Temperature θ'_m	Steam Press. 5 lb. Film Resistance R	Steam Press. 5 lb. Coefficient of Transmission K	Steam Press. 5 lb. Coef. of Trans. Corrected to Stand. Film Temp. of 625 Deg. Ab. K_o	Steam Press. 50 lb. Mean Absolute Film Temperature θ'_m	Steam Press. 50 lb. Film Resistance R	Steam Press. 50 lb. Coefficient of Transmission K	Steam Press. 50 lb. Coef. of Trans. Corrected to Stand. Film Temp. of 625 Deg. Ab. K_o
200	669.9	.0479	3.316	3.354	733.5	.0525	3.322	3.413
300	662.4	.0474	4.674	4.735	723.3	.0517	4.549	4.706
400	655.7	.0469	5.788	5.858	714.0	.0510	5.626	5.838
500	649.4	.0465	6.743	6.841	705.7	.0505	6.565	6.839
600	643.2	.0460	7.614	7.718	697.8	.0449	7.461	7.784
700	638.3	.0456	8.412	8.476	691.5	.0495	8.064	8.403
800	633.5	.0454	9.146	9.204	684.2	.0489	8.829	9.190
900	629.0	.0450	9.823	9.850	678.4	.0485	9.472	9.846
1000	624.7	.0447	10.465	10.455	672.1	.0481	10.063	10.440
1100	620.1	.0444	11.040	11.000	666.7	.0477	10.640	11.020
1200	616.3	.0441	11.610	11.490				
Total Variation	8.00%	7.93%			9.17%	9.14%		

VENTO REGULAR C. I. HEATERS 5 IN. CENTERS STEAM PRESS. 5 LB.

Velocity	Mean Absolute Film Temperature θ'_m	Film Resistance R	Coefficient of Transmission K	Coef. of Trans. Corrected to Stand. Film Temp. of 625 Deg. Ab. K_o
200	672.6	.0511	2.795	2.819
300	666.1	.0507	3.948	3.990
400	660.4	.0503	4.917	4.990
500	654.8	.0497	5.837	5.922
600	649.8	.0494	6.738	6.825
800	640.6	.04875	8.051	8.145
1000	632.6	.0480	9.191	9.255
1200	626.0	.0476	10.160	10.200
1400	619.8	.0471	11.030	11.050
1600	614.3	.0467	11.780	11.700
1800	609.0	.0463	12.505	12.350
	9.46%	9.39%		

heater section, with 5 in. centres. Fig. 13 is plotted for steam pressure of 0 lb. gauge and Fig. 14 for 20 lb.

The dotted lines explain the use of these charts, which is as follows: In Fig. 13, assuming an entering temperature of +10 degrees and a velocity of 1,000 ft. per min. through the clear area, follow the dotted line to the right and then downward to

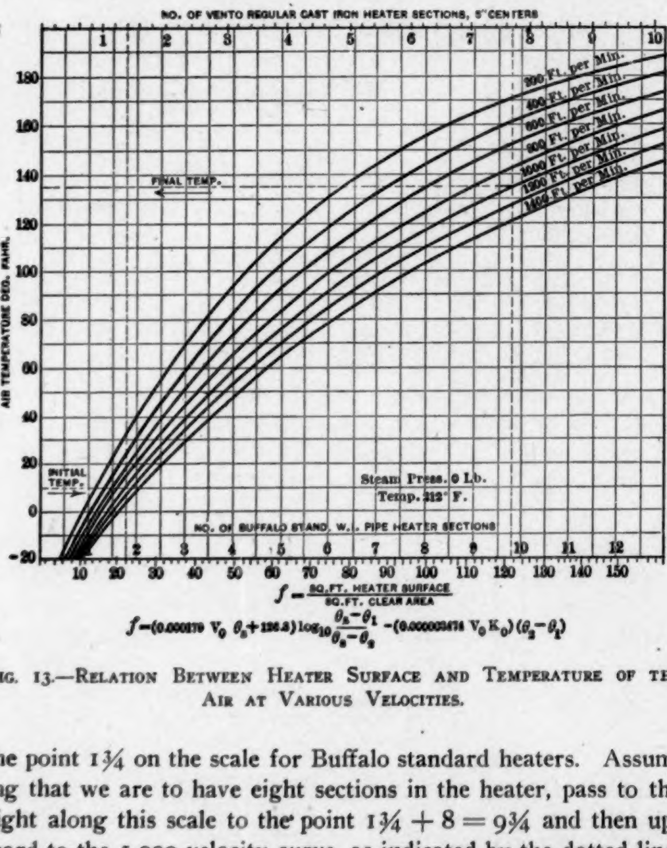
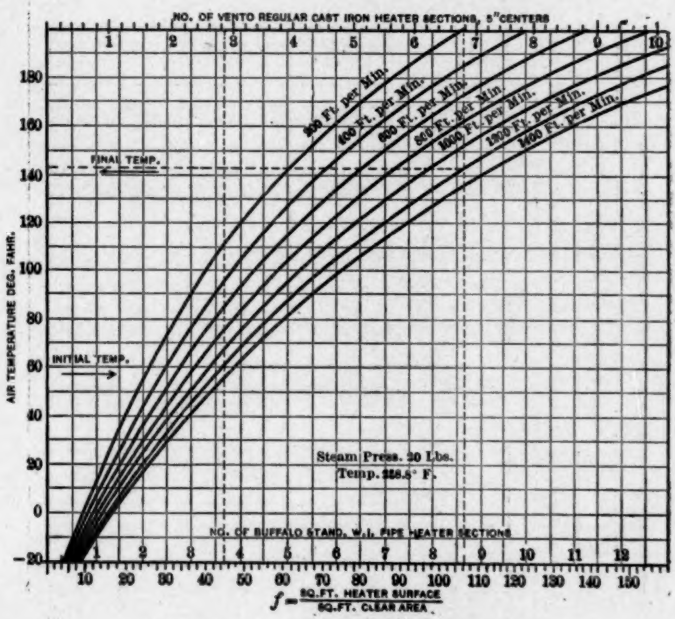


FIG. 13.—RELATION BETWEEN HEATER SURFACE AND TEMPERATURE OF THE AIR AT VARIOUS VELOCITIES.

the point 1¾ on the scale for Buffalo standard heaters. Assuming that we are to have eight sections in the heater, pass to the right along this scale to the point $1\frac{3}{4} + 8 = 9\frac{3}{4}$ and then upward to the 1,000 velocity curve, as indicated by the dotted line. Following the dotted line to the left we find the final or leaving temperature of the air will be 135 deg. To determine how many sections of Vento heater would be required to give the same temperature rise, the dotted lines have been extended to the top or Vento scale. From the intersection points we have 7.7 —

1.4 = 6.3 sections required, and by inspection we may also find that the final temperature obtained with six sections would be 132 deg. In the same manner the amount of surface required to give any certain temperature rise may be determined.

Table 10 shows the final temperature and B.t.u. transmitted per lineal foot of 1-in. pipe with Buffalo standard heaters, for vari-



$$f = (0.000179\ V_0\ \theta_s + 126.8)\log_{10} \frac{\theta_s - \theta_1}{\theta_s - \theta_2} - (0.00000474\ V_0 K_0)(\theta_2 - \theta_1)$$

FIG. 14.—RELATION BETWEEN HEATER SURFACE AND TEMPERATURE OF THE AIR AT VARIOUS VELOCITIES.

ous velocities and entering temperatures when the steam pressure in the coils is 5 lb. gauge. Similar tables may be calculated for any other pressure and entering temperatures.

CONCLUSIONS.

1. The consideration of the above data is apparently sufficient to substantiate the foregoing theory of heat convection. It also appears to establish the fact, from four separate and independent

TABLE 10.—TEMPERATURE OBTAINED WITH BUFFALO STANDARD HEATERS.

Temp. of Entering Air	No. of Heater Sections.	Gauge Pressure 5 lb., Steam Temp. 227° F. Velocity of Air in Ft. per Min., Measured at 70° F. and 29.92″ Baro. 200		400		600		800		1000		1200		1400	
		Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.
-20°	1	23.0	261	17.9	459	14.1	620	11.1	754	8.9	876	6.9	976	5.1	1065
	2	58.0	236	49.5	421	43.1	574	38.0	703	34.1	820	30.2	913	27.2	1001
	3	87.1	216	76.5	390	68.4	536	61.5	659	56.1	769	51.1	862	46.9	946
	4	111.0	198	99.3	362	90.0	500	82.1	619	75.5	724	69.8	817	64.4	898
	5	131.2	183	118.4	336	108.5	467	100.0	582	92.7	683	86.1	772	80.6	854
	6	147.9	169	135.2	314	124.6	438	115.6	548	108.0	647	100.8	732	94.9	813
	7	161.5	157	149.0	293	138.5	412	129.3	517	121.3	612	114.0	696	107.8	775
	8	172.7	146	160.7	274	150.3	387	141.0	488	133.0	580	125.7	662	119.1	738
-10°	1	31.1	249	26.0	436	22.5	591	20.0	728	17.7	839	15.3	918	13.8	1010
	2	64.6	226	56.3	402	50.3	553	45.5	673	41.5	781	37.8	869	34.9	953
	3	92.6	207	82.4	374	74.8	514	68.1	631	62.8	736	57.8	822	53.9	904
	4	115.4	190	104.0	346	95.4	479	87.8	593	81.4	693	75.5	778	70.9	858
	5	135.0	176	122.7	322	113.0	447	105.0	558	97.9	654	91.4	738	86.1	816
	6	151.0	163	138.9	301	128.6	420	120.1	526	112.4	618	105.7	701	99.9	777
	7	164.0	151	152.0	281	141.9	395	133.0	495	125.2	585	118.3	667	112.3	741
	8	174.7	140	163.2	262	153.3	371	144.4	468	136.4	555	129.5	634	123.0	705
0°	1	39.5	239	34.5	418	31.1	566	28.5	691	26.4	800	24.2	878	22.6	959
	2	71.5	217	63.5	385	58.0	527	53.0	643	49.3	747	45.6	829	42.9	910
	3	98.2	198	88.4	357	81.0	491	74.6	603	69.5	702	65.0	788	61.0	863
	4	120.2	182	109.2	331	100.8	458	93.5	567	87.2	661	81.8	744	77.2	819
	5	138.9	168	127.3	309	117.9	429	110.0	534	103.0	624	97.0	706	91.9	780
	6	154.1	156	142.4	288	132.7	402	124.3	502	117.0	591	110.6	670	105.0	743
	7	166.6	144	155.0	268	145.4	378	136.8	474	129.2	559	122.6	637	116.7	708
	8	177.0	134	166.0	251	156.3	355	147.7	448	140.0	530	133.2	605	127.1	674

TABLE 10.—CONTINUED.

Temp. of Entering Air	No. of Heater Sections	Gauge Pressure 5 Lb., Steam Temp. 227° F. Velocity of Air in Ft. per Min., Measured at 70° F. and 29.92″ Baro. 200		400		600		800		1000		1200		1400	
		Final Temp.	B. T. U. Per Lin. Ft. Per Hr.	Final Temp.	B. T. U. Per Lin. Ft. Per Hr.	Final Temp.	B. T. U. Per Lin. Ft. Per Hr.	Final Temp.	B. T. U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.	Final Temp.	B.T.U. Per Lin.Ft. Per Hr.	Final Temp.	B.T.U. Per Lin. Ft. Per Hr.
10°	1	47.6	228	43.0	400	39.5	537	37.1	637	35.0	758	33.1	838	31.5	913
	2	78.3	207	71.0	370	65.3	503	60.8	616	56.8	710	53.5	791	50.9	868
	3	103.7	189	94.5	342	87.4	469	81.2	576	76.2	669	71.9	751	68.0	821
	4	124.8	174	114.4	317	106.3	438	99.2	541	93.1	630	88.0	710	83.7	782
	5	142.7	161	131.7	295	122.7	410	115.0	509	108.3	596	102.6	674	97.7	745
	6	157.3	149	146.1	275	136.7	384	128.8	480	121.6	564	115.6	640	110.1	708
	7	169.2	138	158.8	258	148.9	361	140.5	452	133.2	534	127.0	608	121.2	674
	8	179.1	128	168.7	241	159.3	340	151.0	428	143.8	507	137.0	578	131.1	643
20°	1	55.6	216	51.5	382	48.3	515	45.8	626	43.6	716	41.9	795	40.4	866
	2	85.1	197	78.0	352	72.7	479	68.3	586	64.4	673	61.5	755	58.8	823
	3	109.4	181	100.5	326	94.0	449	88.0	550	82.8	635	79.0	716	75.3	783
	4	129.6	166	119.6	302	111.6	417	104.9	515	99.1	600	94.1	674	90.0	743
	5	146.7	154	135.6	280	127.4	391	120.0	485	113.4	566	108.1	641	103.4	708
	6	160.3	142	149.8	262	140.8	366	133.0	457	126.0	536	120.5	610	115.2	674
	7	171.8	132	161.2	245	152.4	344	144.4	431	137.3	508	131.4	579	125.9	642
	8	181.2	122	171.3	229	162.3	324	154.5	408	147.1	482	141.0	550	135.4	612
60°	1	88.6	173	85.4	308	82.9	417	80.5	497	79.0	576	77.6	639	76.3	692
	2	112.2	158	106.8	284	102.3	385	98.7	469	95.5	538	93.0	600	91.0	658
	3	132.2	146	125.0	263	119.0	358	114.4	440	110.4	509	107.0	570	104.2	625
	4	148.6	134	130.5	244	133.7	335	128.2	414	123.4	481	119.4	540	116.0	594
	5	162.0	124	153.2	226	146.1	313	140.1	389	134.8	454	130.4	512	126.4	564
	6	173.1	114	164.4	211	157.0	294	150.6	366	145.2	430	140.1	486	135.9	537
	7	182.4	106	174.0	198	166.5	277	160.0	347	154.2	408	149.0	463	144.6	513
	8	190.0	99	182.0	185	174.7	261	168.0	327	162.2	387	157.2	442	152.7	492

sources, that there is a true film resistance to the transmission of heat, which varies inversely as the density of the air or gas in the surface film and hence directly as the absolute film temperature.

2. It has been conclusively shown that the rate of heat transmission per degree difference in temperature between the steam and air is not constant for a given velocity, but varies in accordance with the theoretical film temperature. For instance, it was shown that with 5 lb. steam pressure the rate of heat transmission decreased much more rapidly than the temperature difference between the steam and air. A still more striking illustration may be had by a comparison of the values of K in Table 9 between the tests with 5 and 50 lb. steam pressure. This shows clearly that with the higher steam temperature at 50 lb. the rate of heat transmission per degree difference was considerably less than at 5 lb. steam pressure and was in exact accordance with the theory.

3. This effect of film resistance has a very important bearing in many other cases of heat transmission, as, for example, in the indirect transmission of heat in boilers and in the cooling of gases in the cylinders of gas engines. In such cases there are comparatively very high film temperatures which tend to greatly reduce the rate of transmission. At these high film temperatures for the same reason, the per cent increase in the rate of transmission with increased velocities is greatly reduced.

4. The film resistance is the same for all surfaces regardless of their form, but that portion of the transmission resistance which is dependent on the velocity is inversely proportional to the effective velocity and will not be alike for any two designs of heaters.

5. In general it may be stated that when the velocities in the different types of heaters are so modified as to obtain the same frictional resistance, the transmission resistance will be the same. For example, Vento heaters are shown to give a considerable lower transmission than staggered pipe coils at the same air velocity, owing to the difference in the disposition of the surface. But for the same reason the Vento also has considerably lower frictional resistance, so that by increasing the velocity to give the same frictional resistance, the rate of transmission becomes substantially the same in both styles of heaters.

DISCUSSION.

Professor Kent: I would like the author to supplement this paper, if he will, with a brief summary of the important results obtained and of the conclusions derived from them. I would like to know, for example, what are the conditions necessary to heat a given quantity of air to a given temperature. The results to be obtained by any air-heating apparatus are two in number, 1, quantity of air, in pounds or in cubic feet measured, say at 70 deg., and 2, the final temperature desired. To obtain these results we have three features of construction or design, 1, type, cast iron or wrought iron; 2, square feet of heating surface; 3, free area, square feet for the passage of air; and three conditions of operation: 1, temperature of steam; 2, initial temperature of the air; 3, humidity of the entering air. I would like Mr. Busey to give us a statement or formula showing the relation of these six variables to the two desired results.

A Member: Should not friction effect be one of the factors?

Professor Kent: Friction is a function of the velocity, which is the quantity in cubic feet divided by the free area, and also of the quotient of the square feet of heating surface divided by the free area; so that if we have these factors, cubic feet of air, square feet of heating surface and free area, we do not need to consider friction as a factor.

Mr. Barron: There are two concerns in this section, one manufacturing coils, heaters such as the upright return bend type, and the other manufacturing horizontal pipe heaters only; but their data are not referred to, as far as I know never have been referred to; and those concerns I think have the largest body and collection of data and tests in reference to heat transmission. Now I presume there are members of this society who are more or less connected with both of those concerns and can get these data if effort is made, such as is made in other cases, and I think it is what this body should put on record, just as in the gentleman's paper. His paper is excellent, but if we can add these other data which have been worked on for a number of years they would be valuable in our proceedings.

Mr. L. A. Cherry (by letter): In Mr. Busey's paper on "Heat Transmission with Indirect Radiation," it is particularly gratifying to note that we are coming more and more to the use of

rational formulæ in heating matters, and that empirical rules, or, worse still, old rules of thumb, are gradually being discarded.

The author of the paper is to be complimented on the thoroughness with which he has gone into this subject; and the agreement of the figures in the test as compared with those deduced from the formulæ seems to show that he is on the right track regarding the theory of heat transmission.

However, there are one or two items which are not perfectly clear to me, and may not be to others.

"It will be noticed from Table 2 that, while the values of θ_1 and R increase, the value of K, the coefficient of transmission, decreases, the rate being 3.8 per cent."

In Equation 4, there is shown the relation between K and R at the velocity V_0, this equation being used to find approximate values for R and $\frac{B}{C_p\, W_o}$ these values in turn being used to find the corrected value of K—that is K_0.

Now in column 12 in table 2 are shown these values of K for each section from 1 to 8. It will be noticed that, with the exception of K for the sixth and eighth sections, the coefficient decreases quite regularly, and it is only some slight inaccuracy, which will creep in at any time in tests of this kind, that prevents K for these sections from falling along its regular place, as it would if calculated by the formula, results of which are shown in column 11.

In plotting equation 4, it is not stated which of these values of K is used, and while there is not a very great difference in the values, unless the coefficients for the different velocities were taken at about the same temperature difference, there might be some difference in results obtained, and the points might not fall on such a smooth line as they do at present.

A few years ago I had occasion to test some Vento sections under forced blast, and in devising a rational formula for use at this time there was taken as a basis of the calculations a formula which was gotten up by Du Long and Petit, in which they found that the quantity of heat transmission by convection was proportional to $(\theta_s - \theta)^{1.233}$ instead of $\theta_s - \theta$ as assumed by Mr. Busey. This formula gave us very satisfactory results; and the fact that K, as shown in column 12 of Table 2, decreases as the temperature difference between the steam and air passing

through sections decreases would seem to indicate that the heat emission is proportional to some higher power than the first, though evidently not as high as the 1.233 power. From column 12 it is apparent K varies approximately as $(\theta_s - \theta)^{1.06}$, and that if K is calculated on this basis the values would be (neglecting constants) 533, 532, 532, 529, 529, 529 and 532, the coefficient for the eighth section being omitted, as it is a little off color.

As the experiments of Du Long and Petit, followed by Peclet and Ser, were strictly laboratory experiments on very small apparatus, it is more than likely that elaborate experiments such as these conducted by Mr. Busey and Mr. Carrier will give a value for this exponent which is more reliable for blast heater work than that by Du Long and Petit.

I should like to know also whether or not Mr. Busey has made any attempt to use values found in these tests to determine what would be the heating effect if the pipes in the heater were spaced farther apart or closer together, which would change the value of *f*, the ratio of total surface to clear area. In some tests made on Vento we had thought that the formula which we had was a general one and could be applied to most any case by changing the constants, this ratio being one of them. Tests were run with spacings on centers 4 in., 4⅝ in., 5 in. and 5⅜ in., the standard spacing for this style of section being 5 in. The coefficients for the 4⅝ in. and 5⅜ in. fell very closely along the lines of coefficients obtained for the 5 in. spacing, but they were enough different so that we had reason to suspect that the same formula would not hold good by merely changing the value of *f*. Later when tested with 4 in. spacing, this was shown more clearly, as the coefficient curve was quite a distance away from the one obtained from the other three spacings. Evidently at the closer spacing there was a more intimate contact between the air and the heater, so that the particles of warmed air were more quickly removed from the surface and replaced by cold ones. I should like to know if others have had this same experience in the testing of blast heaters.

In explanation of the slight discrepancies which exist in the temperature rise given for low velocities and for a small number of sections, it might be well to mention that these were not run as blast-heater tests at all, but were set up horizontally and

boxed in as ordinary indirect, the circulation of air over the surface being entirely by gravity, as would be the case in an ordinary indirect installation. Only the usual precautions were taken to prevent heat loss through the housing, and consequently there was a larger proportional loss of heat by radiation than would be obtained in a regular blast heater when set up for testing. Little or no importance was attached to the worth of these tests to determine the shape of the coefficient curve, and points were plotted on this chart more for additional information than anything else.

In this paper, the results of tests on pipe heaters at high pressure will give a line of information which has heretofore been very scarce, and as Fig. 10, showing derivation of constants, gives exactly the same results as those obtained from Fig. 5, it is additional confirmation that the theory as worked out is correct.

It is also interesting to note that practically the same results were obtained in heat transmission for pipe heaters and Vento heaters, when the same frictional loss was encountered in the passage of the air; and that this will apply to any form of section, unless the design is so poor that there are portions of the heating surface which are masked so that the air cannot come in perfect contact with the section.

Mr. Busey: In answer to Mr. Cherry's question as to which value of K was used in Equation 4, would say that the experimental value as given in column 12 of table 2 was used.

The value of K will not be the same for pipe heaters having different values of F, the ratio of heating surface to clear area, but as more fully explained in the paper presented before the A. S. M. E. this is taken care of; Formulæ 12 to 14 take into consideration varying values of *f* according to which factors are already known. Any change in the ratio of surface to clear area will alter the resistance and effective velocity of the air, and will change the slope of the straight line. This is clearly shown in Fig. 12 in the plot of the two lines.

CCLXXIX.

STEAM HEATING LARGE DEPARTMENT STORES

ITS RELATION TO THEIR ELECTRICAL REQUIREMENTS.

BY DAVIS S. BOYDEN.

A few years ago one of the largest department stores of Boston had commenced the erection of a new building, which would about double its floor area. Up to this time the store had operated its own isolated electric plant, and plans for a new plant were under way. It was then brought to the attention of those in charge that central station electric service would save the large investment and a considerable amount on the operating costs of an isolated plant.

The operating costs of the proposed plant and the cost of central station service combined with the operating of a steam heating plant were threshed out among several of the best engineers, each one furnishing his own estimates. These estimates on the plant costs and on the electric consumption varied somewhat, but when it came to the cost of operating the boilers for steam heating only, there was a very wide difference in the estimates of the engineers and all were much above the figure estimated by the central station people for operating the heating plant. This wide variation only shows the great lack of information on the subject of steam heating and the fact that its relation to the electric requirement is most generally over-estimated. The central station people received a long term contract for the electric service, and the actual cost of operating the steam-heating plant during the past two years has fallen well within the estimate made by the engineers of the central station company.

The department store occupies three large buildings, the Old Store having a floor area of 273,400 sq. ft., the Francis building having 69,400 sq. ft. of area, and the new building having 295,000 sq. ft., making a total floor area of about 637,-

800 sq. ft. The new and Francis buildings adjoin each other and a tunnel under the street connects these buildings with the Old Store. The Old Store consists of a number of adjoining brick and stone buildings of varying architecture from four to seven stories high, with basement. The new building is of steel construction, terra cotta finish, nine stories high, with basement and sub-basement. The Francis building is also of steel construction, brick finish, eight stories high. The accompanying plan shows the arrangement of the buildings and surroundings.

Steam is furnished from the three 250-h.p. Babcock & Wilcox boilers located in the sub-basement of the new building. These boilers are hand fired, and have projecting furnaces of the so-called Dutch oven type. The boilers are operated only during the heating season, live steam for the small summer requirement being furnished through a steam main from the boilers in a neighboring building.

The steam heating system of the Old Store is of the direct-pressure type, with the exception of the basement, which has an indirect system of heating with forced ventilation. Hand control is used throughout this building, the returns being trapped to the receiver in the boiler room.

The new building and the Francis building have indirect heating on the first floor as well as the basement, this heating being automatically regulated by Johnson thermostats. The direct radiation on the upper floors is fitted with the D. G. C. automatic return valves, which discharge the condensation direct to the open receiver. The pressure carried on the direct radiation varies from 3 to 6 lb., according to the weather.

The radiation surface and other data regarding heating are given in the accompanying table:

DATA OF THE THREE HEATING PLANTS

	Outside Volume Including Basement cu. ft.	Exposed Wall Surface sq. ft.	Exposed Glass Surface sq. ft.	Mechanical Ventilation cu. ft. fresh air per min.	Direct Radiation sq. ft.	Indirect Radiation sq. ft.
Old Store	3,706,700	50,353	17,251	40,000	8,122	1,936
New Bldg.	3,836,000	28,030	26,519	68,000	11,595	4,182
Francis Bldg.	848,300	16,541	7,129	....	4,368	....
Totals	8,391,000	94,924	50,899	108,000	24,085	6,118

TEST OF THE HEATING PLANT.

In order to study the daily load curve of the steam heating plant as compared with the electric load curve and also to determine the efficiency of the boilers, a two days' test was made on the heating plant.

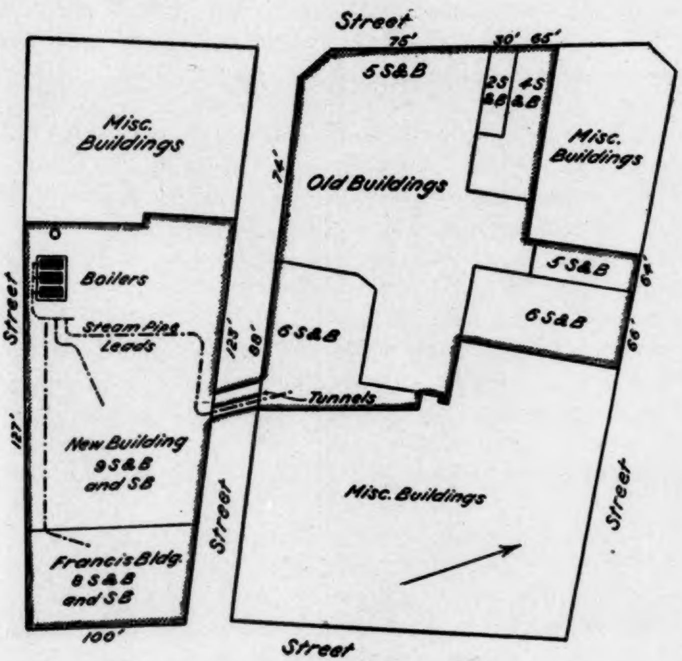


FIG I.—BLOCK PLAN OF THE BUILDING SHOWING BOILER PLANT.

A number of thermometers were placed throughout the buildings and readings taken hourly at two points on the first and third floors and at one point on the fifth floor of the Old Store, and at one point on the first, third, fifth and seventh floors of the new and Francis buildings. Temperatures were also taken on the roof of the Old Store and the Francis buildings while the store was open and access could be had to the roof. The outdoor temperature was taken hourly at the street level near the boiler room door.

On the boiler test, the amount of steam used for heating is

considered to be the total water fed to the boilers, and this is true except for steam used by the boiler-feed pump and the small amount used in the kitchen and for hot water. The feed water was measured by a hot-water meter connected in the feed line. Hourly readings were taken on this meter, care being used to keep a constant water level in the boiler. The coal burned during the test was weighed out in 500 lb. lots as fired, but no attempt was made to keep a record of the coal burned each hour, this being affected by any change in thickness of the fire. Other readings taken in connection with the boiler test were feed water temperatures, boiler pressures, and pressures in the lines to the buildings all taken at 15-minute intervals.

Calibration tests were made on the hot-water meter after using, and a plot of corrections made. The meter was found to read about 4 per cent. low for flows of 2.5 cu. ft. per minute and greater. For less than 2.5 cu. ft. per min, the error increased to as much as 15 per cent. low at 1 cu. ft. per minute, although this should be expected when the meter is designed for measuring a much greater capacity. The corrections from the calibration curve were then applied to the readings of the hot-water meter. The results of the boiler test were as follows:

BOILER TEST

Duration of run, hr	48
Total water evaporated, lb	429800
Total coal burned, lb	47803
Boiler pressure, lb	77.5
Feed water temperature, deg. F	211.8
Water per lb. coal actual, lb	8.98
Water per lb. from and at 212 deg., lb	9.30
Boiler horse power	268.3

AVERAGE PRESSURES ON HEATING LINES

1—Intermediate pressure line, lb	33.7
2—New store, direct radiation, lb	4.03
3—Old Store, direct and indirect radiation, lb	3.46
4—Francis building, direct radiation, lb	1.04

The temperatures at different points in the buildings did not vary widely at any time, and the average for the whole store is used in the plot, Fig. 3. The top curve shows how the average inside temperature varies throughout the day. The temperature falls to 67 deg. during the early morning hours, rising to 70 deg. as the Christmas crowds invade the store. A maximum of 71 deg. is reached when the store closes, the building gradually cooling off again to 67 deg. during the night.

The second curve shows the changes of outside temperature

on this day, which is typical of a December day during settled weather.

The bottom curve represents the coal burned that day apportioned according to the boiler feed water meter readings. The rise in this curve from 1 a. m. to 4 a. m. is due to the turning on of steam in the new building, which had been turned off since six o'clock the night before. The more pronounced rise between 5 and 6 a. m. was caused by the turning on of

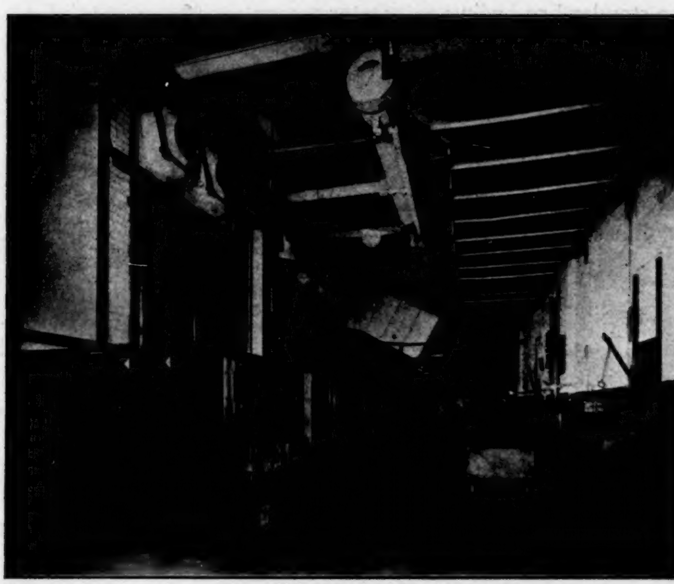


FIG. 2.—VIEW IN THE BOILER ROOM.

steam and the opening of the air cocks in the radiators in the Old Store. The third rise at 8.30 a. m. is due to the starting up of the fans of the indirect heating system. The gradual increase in steam after 3 p. m. follows the setting sun and the drop at 6 o'clock is due to the shutting down of the fans.

To show the close relation between the coal burned each month for heating and the average outside temperature we have made the plot given in Fig. 4. As these quantities vary inversely we have plotted the solid line representing coal burned to read up and the dotted line of average temperatures to read down. The

slight variation in the form of these curves during the heating season is due somewhat to outside influences, such as wind and humidity, but principally to the lack of control of the hand-operated radiator valves. We find that similar curves for buildings having thermostatic control of the heating conform much more closely with one another. An average temperature of 65 deg. is used to represent zero coal demand.

Electric power and light is furnished from the central station, the standard recording wattmeter accurately measuring the electric consumption. An automatic tape device is also connected with the wattmeters to record the exact consumption throughout the day and these records are on file for reference. The present electrical connected load is as follows:

Incandescent lamps	1998 kw.
Arc lamps	653 kw.
Iron and Electric heaters	6 kw.
Elevator motors, 689	514 kw.
Other motors, 287	236 kw.
Total connected load	3407 kw.

The highest demand which has yet been recorded is 1,054 k.w., which is 31 per cent. of the connected load. This is of considerable interest, because in the case of an isolated plant the generator capacity installed would be from 50 to 70 per cent. of the connected load, not allowing for spare units, when less than one-third of the connected load is the maximum which is used for any half hour. The yearly load factor figured on a 24-hr. basis throughout the year is also of considerable interest to the engineer estimating on the electric consumption of this class of building. The load factor, or the ratio of the average consumption to the maximum is only 30 per cent. The ratio of the average consumption to the total connected load is therefore 31 (per cent.) $\times$ 30 (per cent.) = 9.3 per cent.

As all the necessary data are now at hand for the consideration of the operation of an isolated electric plant, we will take up this phase of the subject.

The proposed plant, which was not installed, was to have tandem-compound non-condensing engines, which were estimated to generate 1 kwhr. on 5 lb. of coal, the exhaust steam being passed through a feed-water heater. We will then multiply the hourly electric consumption for December 20 by 5 lb. of coal and plot this as the additional coal required to supply the electric

service. The lack of co-ordination of the two loads is very evident from the plot, Fig. 3, a considerable amount of live steam being used during the night for heating, and by far the greater part of the exhaust from the plant being wasted during the day and evening.

The actual coal burned for heating on this day was 24,000 lb. The electrical consumption for this day would require 60,485 lb. of coal. If the same standard of heating is maintained with the isolated plant as with the heating plant, an additional amount

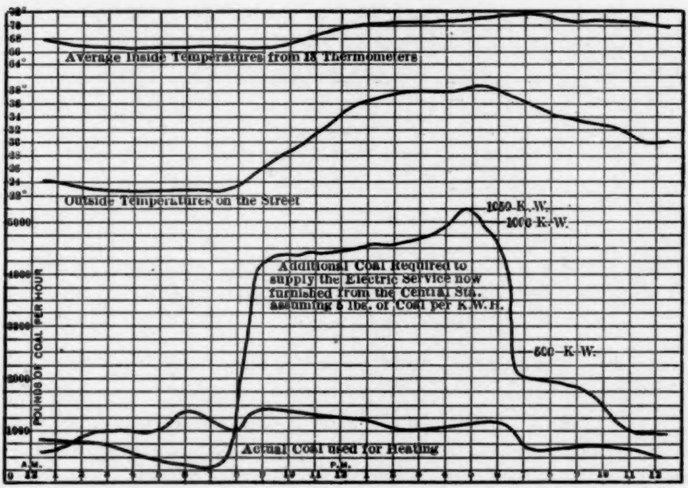


FIG. 3.—RESULTS OF TESTS MADE DECEMBER 20, 1911.

of live steam will be required between the hours of 2 and 8 a. m. This live steam will be equivalent to 4,250 lb. of coal or 17.7 per cent. of the total coal for heating. The total coal used by the isolated plant will be 64,735 lb. The percentage of exhaust from the plant which may be used for heating will then amount to 32.6 per cent. for this particular day.

We will now assume that this is a fairly average day for the heating season, there being colder and warmer weather when more or less live steam would be required. The total coal used for steam heating during the past 12 months was 1,921 tons. We will assume that 17.7 per cent. of this would have been live steam from the isolated plant leaving 1,580 tons as the portion

of the year's coal which might have been furnished from the plant exhaust. The electric current consumed during the past year if the same were generated at an isolated plant would require 6,941 tons of coal, figured at 5 lb. per kilowatt-hour. The portion of this exhaust steam which would be used for heating will be 1,580 ÷ 6,941, or only 23 per cent., the remaining 77 per

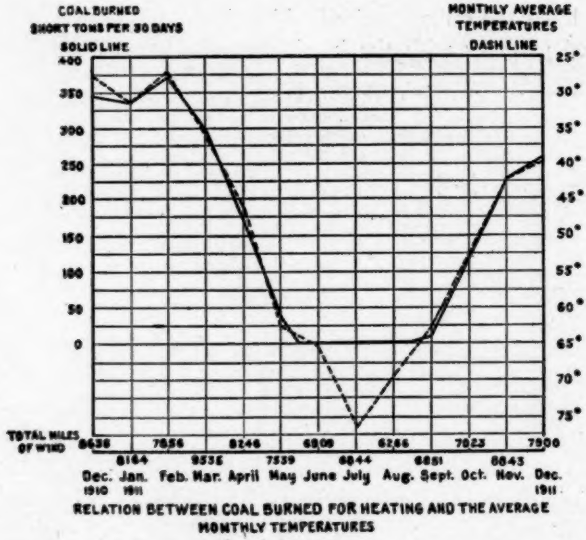


FIG. 4.—RELATION BETWEEN COAL BURNED FOR HEATING AND THE AVERAGE MONTHLY TEMPERATURES.

cent. of the steam being used non-condensing with poor economy.

The total cost for operating the heating plant for the year ending November 30, 1911, was $8,582.29, during which period 2,776,370 kwhr. of electricity were used on the premises. Dividing the cost of heating by the kilowatt-hour use, we find the cost of heating equivalent to 3.0909 mills per kilowatt-hour used. Should we make a reduction of the cost of coal required to furnish the live steam for heating, which is 0.5471 mill per kilowatt-hour use of electricity, we have the total value of the exhaust steam per kilowatt-hour or 2.5438 mills.

ITEMIZED COST OF HEATING WITH EQUIVALENT COST PER KILOWATT-HOUR USE OF ELECTRICITY.

Item	Cost for year ending Nov. 30, 1911	Mills per kw-hr use
Miscellaneous expense	$122.84	.0442
Fuel	5718.14	2.0596
Water	229.94	.0828
Oil and waste	7.35	.0026
Labor	2331.44	.8391
Repairs to mechanical appliances	38.20	.0138
Repairs to boilers	134.38	.0488
	$8582.29	3.0909

It may be a ready means of comparison to append the following deductions.

THE RELATIVE COST OF STEAM AND ELECTRIC SERVICE PER CUBIC FT. OF SPACE AND PER SQ. FT. OF FLOOR AREA.

	Cost per cu. ft. of volume	*Cost per sq. ft. of floor area*
Steam	$0.00102	$0.01345
Electric	.00641	.08436
Total	.00743	.09781

DISCUSSION.

President Bolton: This paper is one of particular interest to those who have had to deal with the operation of testing plants and is a valuable contribution to our records. It brings out in a definite manner one subject of considerable discussion upon which a divergence of opinion exists, owing to lack of such definite information. On page 211 the connection between coal used in heating and the variations of temperature of the exterior atmosphere are shown a relation which can be confirmed by similar comparisons elsewhere, especially in this climate. So close is the relation between the two that in figuring upon the heating requirements of the McCutcheon Buildings in Fifth avenue, we ascertained from the exposures in the usual manner what the zero heating requirements would be and by observation of the methods of fuel consumption we ascertained the amount of coal required to produce a boiler horse-power hour. Basing the heating work upon the average temperature of the season we arrived at a theoretical coal-consumption for the season. On examination of the records we found that we came within twenty tons, or within five per cent. of the actual annual consumption in heating the buildings.

Other observations could be stated of a similar character. In other words, mainly through the good offices of members

of this society, we have arrived at a definite conclusion; namely, that the amount of steam used in heating buildings does follow the variations of exterior temperatures. That is valuable information, and the more we can get of such definite observations and tests as those that are presented in this paper, the better we shall be informed on a subject which is of very great importance to the designing engineer. Many of us—I have felt the same difficulty myself—may have had plenty of experience in the design or installation of plants, but lack definite information as to what happens afterwards in their operation.

CCLXXX.

VACUUM HOT WATER HEATING.

(BY FORCED CIRCULATION.)

BY IRA N. EVANS.*

Hot-water heating by forced circulation has been on the market in various forms for about 18 years, but the majority of owners and engineers have but slight conception of its possibilities, as there is a dearth of literature on the subject. All systems of hot-water forced circulation require a pump in the circuit, but differ in the forms of heaters and their connections and methods of handling the steam and condensation. In the first installations the pumping capacity was comparatively small in proportion to the heating surface and this error has caused many installations to be inefficient to operate and costly to install.

The hot-water system by forced circulation comprises the following apparatus in a completed circuit. 1, a live-steam heater utilizing steam direct from the boilers under high pressure; 2, an exhaust heater for the use of exhaust steam from power either at atmospheric pressure or below; 3, two turbine pumps, either motor or steam turbine driven, for the mechanical circulation of the water. The pumps and heater should be connected by the water pipes in series with by-passes and valves, as shown in Fig. 1. 4, mains, piping and radiators, which transfer the heat to the space heated, thus completing the circuit. There have been many variations of the arrangement, none of which have proved so satisfactory in operation. Hot-water boilers have been used, displacing the live-steam heater, and a reducing valve connection is sometimes made to the exhaust heater for a live-steam connection when the exhaust steam is insufficient. The use of hot water boilers is obviously poor practice, as the regular steam boilers when not operated for power are available to furnish live steam for heating. The hot water boilers would be idle in sum-

*Non-member; consulting engineer, New York City.

mer and the fires are difficult to regulate to suit outside temperature changes.

There have been quite a number of systems installed which use the heat from annealing ovens and economizers with a hot-water forced circulation circuit. The high cost of economizers makes their use for hot water heating questionable, especially as the high temperature of the flue gases makes them available for feed water purposes under all conditions, whereas the heating plant is inoperative in summer. The amount of work any economizer will do is dependent on the quantity of coal burned at any time under the boilers, regardless of the size, and the limiting temperature of the gases that will not interfere with the draught. Where an economizer is installed for feed purposes and the power is inoperative nights, it pays to cross connect it with the heating system and it will absorb about 15 per cent. of the heat of the coal burned at that time. It usually does not pay to install an economizer solely for heating purposes, due to the high temperature available for feed water. However, due to the larger volume and velocity of the water passed through it when operated for heating, the rate of transmission is high.

Another arrangement advocated is the placing of the live-steam heater and exhaust-steam heater in parallel as regards the water connection, but this has the effect of reducing the capacity of the heating surface in the heaters if used together, as only one-half of the water in the system flows through each heater, reducing the velocity. The higher temperature steam available in the live-steam heater over the temperature of the exhaust in the other makes the advantage of the series connections apparent.

The live-steam heater, as indicated in Fig. 1, is placed over the boilers as high as conditions will permit, to obtain a gravity return for the all-live steam used on the system. The condensation returns to the rear drums of the boilers by gravity at nearly the same pressure and temperature as the water in the boilers. When the condensation of the steam is so heavy that the pressure in the heater is reduced below that of the boiler to an extent greater than the column of return water between the level of the water in the heater and the water line of the boilers, the operation is as follows: An injector tee J and a separate 1-in. steam line from the boilers inject the water back into the boilers and overcome the difference in pressure between the heater and boiler. This in-

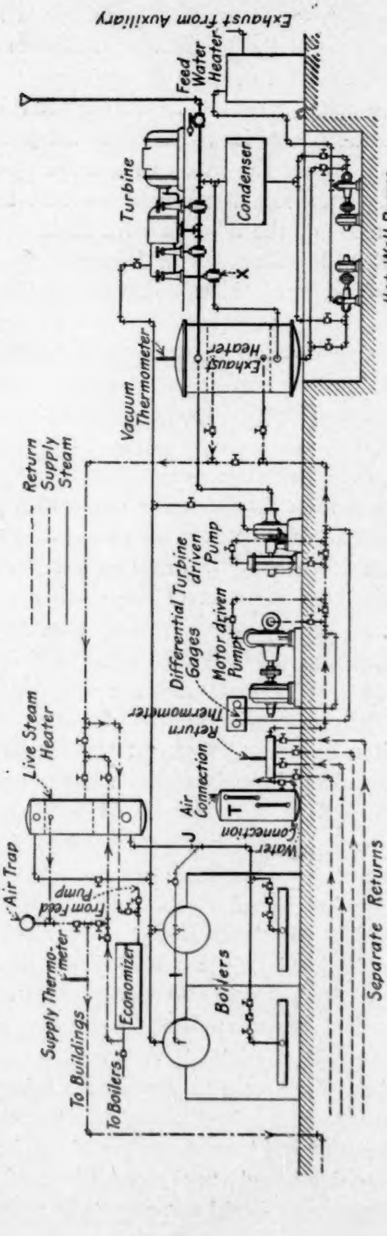


FIG. 1.—DIAGRAM OF CONNECTIONS OF HOT-WATER HEATING SYSTEM.

jector will generally be required if there is less than 10 ft. between the water line of the boilers and the bottom of the heater under conditions of extreme service.

When only a portion of the heater capacity is required the steam valve to the heater is throttled to the point desired, and the condensation covers the tubes, thus reducing the amount of exposed heating surface automatically without interfering with the equal expansion of the tubes and the shell.

When the throttle valve on the heater is wide open and a further capacity is desired, the injector tee is employed. The fact that the bottom of the heater is full of water at a lower temperature and pressure than the boiler makes the conditions favorable for the action of the injector. It should not be unnecessarily used; warning is given by a slight snapping in the return pipe which shows that it is emptying.

When a pump and receiver are used with a live-steam heater the latent heat in the exhaust of the pump nearly equals or exceeds that in the returned water, and as a rule a vapor pipe is provided on the receiver and a drain trap is placed between the receiver and the heater. Part of the discharge from the trap will reevaporate, because the pressure is lowered and is lost through the vapor pipe. The difficulties with pumps handling condensation at high temperatures are well known.

In practice there is nearly the same loss and effect in passing steam through a reducing valve, due to wiredrawing, etc., as in passing the steam through a steam engine, notwithstanding the superheating effect.

The boiler steam is surrounded in the heater by the circulated water, and except for the slight radiation from the efficiently covered shell any loss by releasing the pressure from the condensation is impossible. Both water and steam circuits are hermetically sealed, and what heat is not passed into the heating system must go back to the boiler in the condensation under nearly the same pressure and temperature as the boiler steam, only the latent heat being utilized. This is in direct contrast to the method of reducing the boiler steam to nearly atmospheric pressure and handling the condensation by a pump or other method involving a release of pressure and loss of vapor and condensation.

The losses are due largely to the conditions of practical operation and in many cases would not appear in a theoretical discus-

sion. They may be considerable when the vacuum pump of an exhaust-steam apparatus requires a stream of injection water as large as 1¼ in. to cool the return, as this is entirely overflow with reference to the heating system itself. If a live-steam heater of a hot-water system is connected with pumps or traps its economy is destroyed, and the live steam may just as well be turned directly into the exhaust heater.

For the above reasons when live steam is handled direct to the boiler by the injector method there is a saving of about 10 to 15 per cent. on the amount used, and the difficulties in the proper connection of a return trap are avoided.

The live-steam heater should have a capacity sufficient to heat the water for the entire plant under maximum conditions without the exhaust heater. When operating on a condensing plant the connection between the engine or turbine and the condenser are made as indicated; the amount of vacuum on the heater regulates the water temperature and is controlled by opening or closing the valve X. There may be full vacuum on the condenser with other units exhausting into it. The dry-air pumps and condenser circulating pumps are not shown. The hotwell pumps handle the condensation from the condenser and heater and are cross-connected. They discharge to the open feed-water heater. If the heater can be placed above the condenser the same hotwell pump could handle the condensation from both.

The remainder of the valves about the heater are for shutting it out when operating under full vacuum. This change is made with this arrangement without stopping the main machine.

It is impossible to get perfect operation under all conditions by combining the heater and condenser in one machine. The power determines the amount of steam furnished and the rate per kilowatt-hour is fixed by the amount of vacuum desired to heat the hot water for any given condition of outside weather. When the plant is to be operated non-condensing the steam connection to the exhaust heater leads to the atmosphere in the usual manner without a back-pressure valve. The only reason for using a back-pressure valve occurs when the exhaust heater is too small and it is desirous to raise the pressure and temperature of the exhaust steam. This has the effect of increasing the amount of steam available by creating a back-pressure on the engines. It might also occur that when the exhaust steam just balances the heating,

by the use of a relief valve a vacuum might be created by the heating system corresponding to the temperature of the outboard water. When the live and exhaust steam heaters are connected so that the condensation of both is handled by a pump and reservoir, the live steam heater might be omitted and a reducing valve and back-pressure valve connection made to the exhaust heater. It will readily be seen that where the exhaust heater is operated below atmosphere a trap will be useless for removing the condensation unless sufficient fall is available. The two heater arrangement, as described, embraces all the operating advantages of a high-pressure steam system and a low-pressure vacuum system without the disadvantages of either, outside of the initial cost of heaters and pumps. The circulation on the water system is independent of the temperature of the medium.

When the exhaust steam is inadequate in extreme weather and sufficient in average weather, in the case of a non-condensing plant, it is economical to install a live steam heater with a drain trap, flashing the condensation into the steam space of the exhaust heater, with a pump to remove the condensation at the low temperature from the latter. During periods of moderate weather when the live steam heater is not required a vaccum corresponding nearly to the temperature of the outboard temperature of the heating water may be carried. This would be uneconomical were a large quantity of live steam required nights, on account of the necessity of pumping the condensation to the boilers.

HEATERS.

There is a diversity of opinion as to the merits of iron tube heaters for this work over the regular feed-water heater of the closed type with brass tubes. The brass or copper tubes have about twice the transmitting capacity due to size and thickness of the iron tube surface. The brass surface has a transmission of about 400 to 800 B.t.u. per hour per degree difference between the average temperature of the water and the temperature of the steam. The iron tube surface has about 200 B.t.u. per hour. The iron-tube heaters are about twice the size and the cost is about one-half for the same capacity as the brass-tube heaters. As hereinafter described the steel tubes under certain conditions

are liable to pit, while the conditions for electrolytic action in the brass-tube heaters are ideal.

If the first cost is more important than the space occupied the iron-tube heaters should be selected. If space is an object or the heaters have to be placed in a horizontal position, the brass-tube heaters should be the ones selected. The iron-tube heaters, when placed in a vertical position, require no provision for expansion, as the tubes and shell being the same material and surrounded by fluid at the same temperature at the different levels are under conditions of equal expansion.

Manufacturers generally prefer to put the water through the tubes with the steam outside. In building iron-tube heaters it is customary to reverse this order on account of construction. The exhaust heater has a large diameter, and the bolted heads are expensive to make tight unless the lighter pressure is within the tubes; and the heavier water pressure is held between the tube sheets with the expanded tubes. In the live-steam heater the same method is followed, but as the diameter is much less the practice can be reversed if desired. Two-inch charcoal-iron boiler tubes are found to be the most economical size for surface in these heaters unless they are exceptionally long. Fig. 8 shows the details of a well proved design for a live steam heater. The length, diameter and number of tubes are determined by the available space and capacity required.

The large area around the tubes allows a low velocity through the heater with a minimum drop in friction head. This is a contrast to passing the water through very small tubes at a high velocity with a corresponding drop in friction head of 10 or 20 ft.

In the use of brass-tube heaters, the construction has been the same as for feed-water practice, the water passing through the tubes with comparatively low velocity and small volume. In hot-water heating these conditions are reversed. The velocities in the mains should be from 5 to 10 ft. per second for satisfactory results and first cost. When the tubes are made small the friction head increases rapidly, and if the area is increased to minimize the friction head, the velocity is reduced. The author believes that nothing less than 1½-in. tubes should be used for this purpose to maintain the velocity through the heater and not increase the friction head unnecessarily.

If a 10-in. main is taken as an example at 10 ft. per second

the required number of tubes of ¾, 1, 1¼ and 1½-in. diameter to give the same drop in friction head per unit of length is shown in the accompanying table, and the area will have to be increased proportionately and the velocity reduced.

Size of tube, in.	¾	1	1¼	1½	2
Number of pipes having the same friction as 10 in. tube	651	349	170	114	59
Number of pipes having the same area as 10 in. pipe	149	91.7	52.6	38.65	23.4
Ratio of reduction in velocity in maintaining same friction loss as occurring in the 10 in. pipe	0.22	0.26	0.31	0.34	0.4
Increase in area in number of times, over the 10 in. pipe for the same friction per unit length	4.54	3.85	3.23	3	2.5

It is desirous to maintain high velocities through the heater to increase the transmission, and the use of small tubes defeats the very object except at the expense of friction head. It will be seen that the area would only have to be doubled with a 2-in. tube to obtain the same drop in friction, and if the area of the pipe was taken in 2-in. tubes doubling the friction head for the length through the heater, the velocity would be the same in heater as in the main, or 10 ft. per second, and the friction head loss would not be excessive through the heater. If a ¾-in. tube were used and the same velocity or area maintained, the friction would be 4½ times.

PUMPS.

When the exhaust of the main units is sufficient, it is good practice to use one motor pump and one steam-driven pump for use when the main engines are inoperative. These pumps should be of the turbine type with hollow bronze followers of proper head and capacity. The connection should be made in series, as shown in Fig. 1, and each pump should be of ample capacity to handle the entire plant. As it is only the expense of one or two valves it is best to so connect them in series that both can be operated at the same time. The standard pump may be all right for the circulating head and too light for the static pressure. These data should be given the manufacturer that he may strengthen the casing if necessary. Solid follower pumps are very inefficient, and it is preferable to use high-speed hollow bronze follower turbine pumps with motors or steam turbines for prime movers.

If the main is sufficiently large they can be operated in parallel, and then they are at a disadvantage when operating singly.

These connections are especially advantageous where the exhaust steam is used under partial vacuum in extreme weather. The average temperature of the water may be reduced 5 or 10 deg., which counts heavily in the reduced vacuum required when near atmosphere. There is nothing gained by operating two pumps having the same head and volume in parallel when the mains and plant are designed so that one pump is sufficient. The frictional resistance of the piping is constant for a given velocity, and varies as the square, and the only way the discharge can be increased is by placing the pumps in series and adding the operating head of each pump together. Piston pumps have been abandoned, as they are not applicable to low heads and large volumes, and with the static head balanced on the supply and return the pump valves make a racket that is heard throughout the piping system.

The apparatus should be full of water with 15 pounds above the static head, and entirely free from air for good results. The pumps should have to operate only against the friction head of the piping. The water should be circulated as rapidly as possible at all times, thus reducing the temperature drop and the average temperature of the circulated water. Changing the temperature of the heating system by varying the amount of steam introduced into the heaters is better practice than varying the speed of the pumps and the circulation.

The rapid circulation also increases the transmission of the surfaces in both heaters and the radiation thereby increasing their efficiency.

It has been found by actual experiment that about 80 per cent. of the mechanical energy of the pump reappears in heat which is absorbed by the circulated water, therefore slightly raising its temperature. The friction and consequent heat are caused by the rapid movement of the water against the sides of the pipe. As the exhaust steam from the prime mover of the pump is also used in the heater it will be seen that ample circulating power is not so expensive as at first considered.

EXPANSION TANK.

There are two methods of providing for the expansion of the water, one as shown in Fig. 1 with the expansion tank at the

base of the system and the other as in Fig. 2, where it is placed at the highest point. The cubic contents of the tank can be readily calculated in any case by allowing 150 deg. rise in temperature and about 1½ pints of water for each square foot of radiation. The tank is kept about 25 per cent. full of water. The water level is manipulated by hand by using the air pressure to

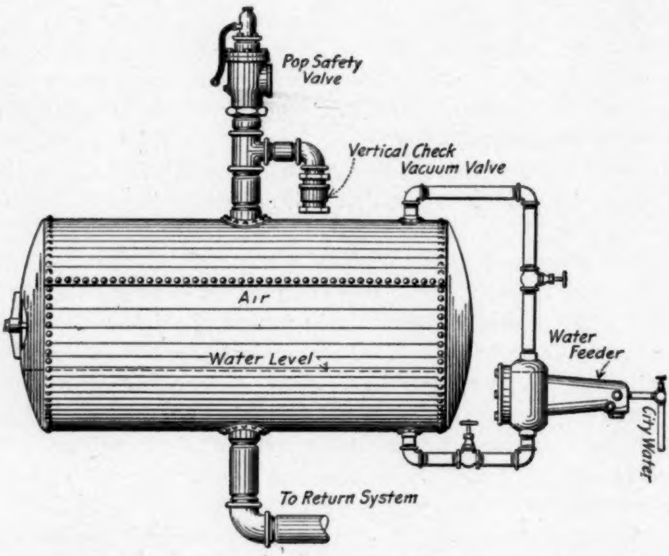


FIG. 2.—EXPANSION TANK AND CONNECTIONS AT HIGH POINT.

force water into the system and is always under the eye of the operator who is immediately advised of any loss of water in the system by the change in the level in the tank.

An automatic air trap releases displaced air at the top of the system by opening when no water is present and closing when the water raises the float. In smaller installations and places where the construction compels the use of the overhead expansion tank with the water feeder, it should be arranged as in Fig. 2. Gauge glasses should be provided to show the water level in all cases. In large installations where air pressure is available, the arrangement in Fig. 1 is preferable.

MAINS.

The mains should be designed with the use of a well-tried friction formula. The one the writer uses is

$$h = f\frac{l}{d}\frac{v^2}{2g}$$

and $q = a\ V\ W$ in which
h = loss in head in feet.
f = factor for different sizes and velocities.
l = length in feet.
d = diameter in feet.
v = velocity in feet per second.
g = 32.2, or the acceleration of gravity.
q = quantity per minute in pounds.
a = area of pipe in square feet.
V = velocity in feet per minute.
W = density in pounds per cubic foot at the average temperature.

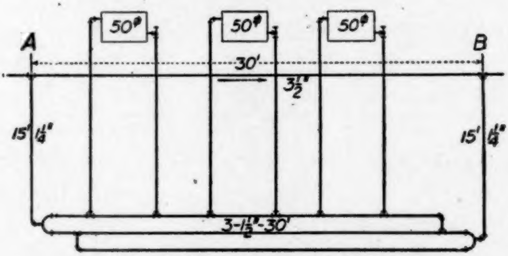


Fig. 3.—Riser Diagram to Illustrate Shunt Calculation.

The drop in head on all circuits should be nearly the same and equal to the total head of the pump. This makes the design of all mains dependent on the velocity and discharge, which gives different size mains in many cases for the same amount of heating surface.

Fig. 3 shows the riser diagram and scheme of arrangement of mains for the new Montefiore home, New York City, Arnold Brunner, architect, and A. M. Feldman, consulting engineer. This is a very satisfactory arrangement. There is a single supply on the basement corridor ceiling and a separate return for each building in the tunnel, the arrangement thus enabling the engineer to control the circulation to each building independently. A valve and thermometer are provided at the return header in the engine room for each return. The separate return will not cost much more than a large single return and the advantages gained fully warrant the arrangement. All the buildings are supplied with an overhead system with single risers. The radiators are shunted off from the riser with a 1¼-in. connection and there is a total of 60,000 sq. ft. of heating surface on the plant.

An application of the method of working on the basis of the formula given may be made in connection with Fig. 3, particularly to find the relation of velocities in the main and shunt and also the dropping temperature with a 1¼-in. connection; thus:

$$30 \div 2.3 = 13 \text{ sq. ft.}$$
$$30 \times 3 \div 2 = 45 \text{ sq. ft.}$$

say, 70 sq. ft. of surface in the coil + 150 = 220 sq. ft.

Assume the maximum water temperature at 210 deg. and the room temperature at 60 deg. or 150 deg. difference; also 1.8 B.t.u. as the transmission factor. Then $220 \times 1.8 \times 150 = 59,400$ B.t.u. per hour required.

$$59{,}400 \div 60 = 1{,}000 \text{ B.t.u. per minute.}$$

Area of 1¼ in. pipe is 1.50 sq. in.; the diameter 0.115 ft.
Area of 1½ in. pipe is 2.04 sq. in.; the diameter 0.134 ft.
Area of 3½ in. pipe is 9.9 sq. in.; the diameter 0.297 ft.

The length of the three 1½-in. pipes to terms of 1¼-in. pipe is $3 \times 2.04 \div 1.5 = 4.08$. Thus the velocity in the coil will be 1/4.08 of that in the 1¼-in. pipe.

The velocity varies as the square, so

$$(1/4.08)^2 \times 30 \text{ (ft.)} = 30 \div 16.7 = 1.8 \text{ ft.,}$$

the length of 1¼-in. pipe to be equivalent friction of the three 1½-in. pipes. The relative lengths will be 31.8 or 32 ft. for 1¼-in. and 30 ft. for the 3½-in. pipe. The drop in head regardless of velocity between points A and B will be the same for both shunt and main.

For this discussion, we will assume the same friction factor, 0.02.

$$h \text{ for } 1\tfrac{1}{2}\text{-in. pipe} = f^1 \frac{l^1 \; v^{1\,2}}{d^1 \; {}^2g}$$

$$h \text{ for } 3\tfrac{1}{2}\text{-in. pipe} = f \frac{l \; v^2}{d \; {}^2g}$$

Cancelling common factors:.

$$0.02 \times \frac{32 \quad v^{1\,2}}{.115 \quad 2g} = 0.02 \frac{30 \quad v^2}{0.297 \times 2g}$$

$$v^{1\,2} = 0.363\, v^2$$
$$v^1 = 0.603\, v; \text{ also } v = 1.66\, v^1$$

or the velocity in the shunt will be 0.603 that of the main.

$9.9 \div 144 \times 6 \times 60 = 24.75$ cu. ft. of water per minute flowing, assuming a 6-ft. per second velocity in the 3½-in. pipe determined previously by the requirements of the buildings supplied. Then

$$24.75 = \frac{9.9 \times 1.66\, v^1}{144} + \frac{1.5\, v^1}{144}$$

from the fact that the area of the shunt times its velocity plus the area of the main times its velocity must be equal to q or 24.75 cu. ft. per minute.

$3564 = (16.5 + 1.5)\, v^1$

$3564 \div 18 = v^1 = 198 \quad 198 \div 60 = 3.3$ ft. per second in the 1¼-in. shunt.

$3.3 \times 1.66 = 5.5$ ft. per second, the velocity in 3½-in. main within the shunt.

solving for the friction head in both, which is equal,

$$h = f\frac{l}{d}\,\frac{v^2}{2g} \text{ and } f = 0.0295$$

$$h = 0.0295\,\frac{32\ (3.3)^2}{0.115\ \ 2g}$$

$h = 1.33$ drop in head for the coil.

When the radiator is first turned on, the contained cold water has to be raised to the main and the pressure due to gravity which has to be overcome will be as follows: We will assume as a maximum the water in the main is 200 deg. and that in the coil 50 deg.

Water weighs at 50 deg.	62.41 lb. per cu. ft.
Water weighs at 200 deg.	60.14 lb. per cu. ft.
Differences.	2.27 lb. per cu. ft.

$2.27 \div 144 = 0.016$ lb. per sq. in.

$h = 2.3\,p$, in which h is the head from Merriman's "Hydraulics."

$0.016 \times 2.3 = 0.0368$ ft. head for each foot of height.

as there is a 15-ft. rise in the pipe, the head due to gravity to be overcome will be

$$0.0368 \times 15 = 0.55 \text{ ft. head.}$$

As the friction head is 1.33 ft., this will be sufficient to raise the cold water and start the circuit, and as the cold water is displaced, the 0.55 ft. head will be reduced to 1/15 when the coil is circulating normally, or $0.55 \div 15 = 0.036$ ft. if the drop is 10 deg.

$1.5 \div 144 \times 60 \times 3.3 = 2.06$ lb. per second.

$2.06 \times 60 = 123.6$ lb. per minute.

1,000 B.t.u. $\div 124 = 8$ deg. drop in the coil under maximum conditions. This is not exactly correct, as the friction

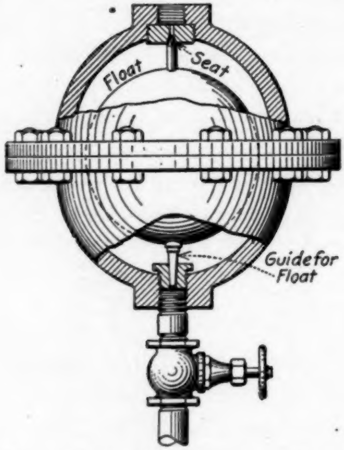


FIG. 4.—COMMON FORM OF AIR TRAP.

factor for 3½-in. pipe is 0.025, and the velocity is 5.5 ft. per second, but it would not make any material difference.

Provision should be made to relieve the air at all high points by automatic air traps, but using as few as possible. Any good drain trap turned upside down and so constructed that the valve is above the water level when closed will answer the purpose. If the trap valve is not out of the water when closed, a slug will be blown out each time it discharges. It should be so connected that a vacuum cannot be produced in the trap when it is closed and hold the water level higher than that in the system, thus preventing its operation. The discharge should, in any case, be connected to some point so that if it does leak it will do no damage.

A sketch of a common form of air trap is shown in Fig. 4. These must be carefully tested before being put in place, as they

are very liable to leak and not seat properly. Dirt will tend to accumulate in the outlet when the traps do not operate for a considerable time; this dirt works down on the seat of the valve and prevents it from tightly closing. For these reasons the reversed steam-drain trap with its float and lever will give greater satisfaction, there being more pressure to seat the valve.

All radiators should be provided with key air valves whether needed or not. Where mains are reduced, ecentric fittings or reducers should be used so that the level of the top of the pipe will be maintained without air pockets. The piping should be so arranged and sized that no bypasses or short-circuits occur. The velocity necessary on a proper working hot-water system should be something over 5 ft. per second in the mains, depending on the size, distance and total head on the pump.

Lock stop valves should never be used to equalize the flow for different sections or radiators; in cases where this is made necessary the arrangement of mains is at fault. Individual regulation of the different sections should be at the main header in the engine room only.

The same velocities cannot be used for the mains throughout on a hot-water system on account of the wide range in loss in head per unit distance of length for the different pipe sizes. The mains cannot be designed properly according to a constant number of square feet of heating surface for each commercial size, as the drop in temperature on the system, head on the pump and distance vary the discharge of water. A 2-in. pipe may take care of 2,000 sq. ft. of surface in one portion of a plant and be too small for 1,000 sq. ft. in another section. These points are mentioned as many plants have been laid out on this basis and may have worked fairly well, but due to poor and unequal circulation the main advantages of the system are lost, viz., small drop in temperature, low temperature of outboard water in extreme weather. The entire system may operate on 10 deg. higher temperature of water just to meet the requirements of a small percentage of the heating system.

The proper discharge in gallons and total head should be carefully determined in advance so that the pump manufacturer may furnish a properly designed pump. It is then good practice to see that he delivers what is called for by measuring the head and gallons after installation. Many cases have occurred where the

manufacturers' test curves showed proper design and when the apparatus was installed an overload was found on the named capacity and head.

Due to the practice of using low water temperatures and large differences between the supply and return on gravity water systems, the idea has become prevalent that hot-water systems require more radiation than for low-pressure steam. This is not so as the circulation of steam, even when vacuum is applied, is apt to be hindered by air at times, or if the pressure is very low and the connections are small, a vacuum may be produced in the radiator, thus cooling a portion of the surface because of the heavy condensation and inadequate steam supply. This occurs often on indirect radiation with cold air supply.

In the case of hot water with forced circulation, due to the high specific heat of the water and a positive and rapid circulation, the transmission of the heating surface is greater than with steam for the same temperatures. If the water is operated at a temperature of 200 deg. average, with a drop on the system of 20 deg. or less, the same amount of radiation will be ample that would be required for a steam system operated at atmospheric pressure, or 212 deg. The maximum temperature of the water is determined entirely by that of the gases or steam used in the heaters. If high-pressure steam is used with no exhaust the water may be circulated up to 280 deg. and a corresponding reduction made in the amount of heating surface installed over a system designed to operate on 200 deg. and below.

It is safe to calculate the radiation for water systems of this type in the same manner as for steam systems with the same temperature and corresponding pressure, with the added assurance of a positive circulation.

Leaks can be eliminated by proper testing, inspection and selection of the material entering construction. The fittings should be of the heavy water pattern, such as are required for sprinkler work, of good iron and tapped solid with no bushings, as they invariably are the source of leaks. Fifty pounds of steam should be used as an expansion test on the piping before the radiators are connected. The radiators should be tested to 100 lb. before being placed in the building and the whole system should then be tested to 100 lb. before and after the radiators are connected and before the system is placed in regular service.

All water radiators have a top and bottom connection to each section, and the supply connection is always made at the top of the radiator. In this type of radiator steam circulates 50 per cent. better than in the regular steam radiator with a single bottom connection, and the difference in price is very little. Owners and architects would do well to insist on the use of double-connection radiators, whether steam or water were used, as the system would be interchangeable at slight expense and the circulation would be better.

It often occurs that 300 or 400 h.p. in boilers are required for the heating of a large building, whether the electric power is furnished or not. Has it ever occurred to the engineer or owner that this same heating system, if made air-tight, would have the power to act as a condenser to produce vacuum and would thus greatly increase the power economy over non-condensing conditions?

The commercial cast-iron radiator is unsafe under a water pressure greater than 100 pounds, so that hot-water heating has been limited to buildings of less than 14 stories, where the static pressure will be within the stated limit. As these buildings have become greater in height and area, the power load for lighting and elevator service has increased proportionately. Due to the mechanical difficulties of making the piping air-tight, it is impossible to take advantage of the increased surface of the steam-heating system to produce vacuum on the engines. They are operated at atmosphere, and the exhaust steam is utilized in the heating system at the same pressure.

The necessities of the low-pressure steam-heating system have eliminated all consideration of a condensing plant outside of the expense of using city water for injection. The same considerations have prevented the use of the turbine, inasmuch as this type of machine is very costly to operate under back pressure or no vacuum, the steam consumption being about 45 lb. per kilowatt-hour on a 500-kw. unit exhausting at atmospheric pressure at full load.

The engines for high buildings are seldom compounded, and the whole subject is no further considered than the fact that exhaust steam is required for heating, seven months, and the amount is estimated under the conditions of no back pressure in zero weather. This fixes the heating-surface temperature at 212

deg. at all times, and observation in the afternoon in most office buildings will show open windows with the radiators turned on, thus wasting the heat to the outside. If the system could be operated at lower temperatures, this waste could in a great measure be eliminated.

The hot-water system may be applied to the highest buildings, the engines or turbines operated condensing and the temperature of the circulated medium varied so that without shutting off the radiation the rooms will not be overheated. The most economical feature in the operation of such a system is the fact that the temperature of the water can be varied from 200 to 100 deg. with a corresponding saving in heat whether exhaust or live steam is used for heating. No more heating surface is required than for vacuum systems as the medium in zero weather is at the same temperature in both cases.

Figs. 5 and 6 show diagrammatically how a hot-water system may be arranged for a building of any number of stories, the power plant operated condensing all of the time and the heating system utilized as a condenser to the extent of its capacity at any given outside weather condition. To reduce the static pressure on the radiators the system is divided into several independent units, utilizing the steam from a common source.

For buildings 12 stories and under, one system is all that is necessary regardless of the area covered, and the heaters and pumps would be placed in the basement, but the condensing feature hereinafter described could be applied. For buildings under 20 stories and more than 12, two systems would be required, and for buildings 20 or more stories in height every 10 stories would require a separate system or unit. The heaters and pumps can be placed in a room of little value. Places of this character, such as a poorly lighted room, can be found in almost all buildings, and at that the required space would not be more than 15 x 20 ft. on every tenth floor. The most advantageous place would be next to the shaft carrying the boiler flue and exhaust piping. The separate heaters and pumps can all be placed in the basement by installing long vertical supply and return water pipes. The heaters would then have to be built to withstand the static pressure, but the pressure on the radiation would be within safe working limits.

The arrangement shown contemplates one supply and one re-

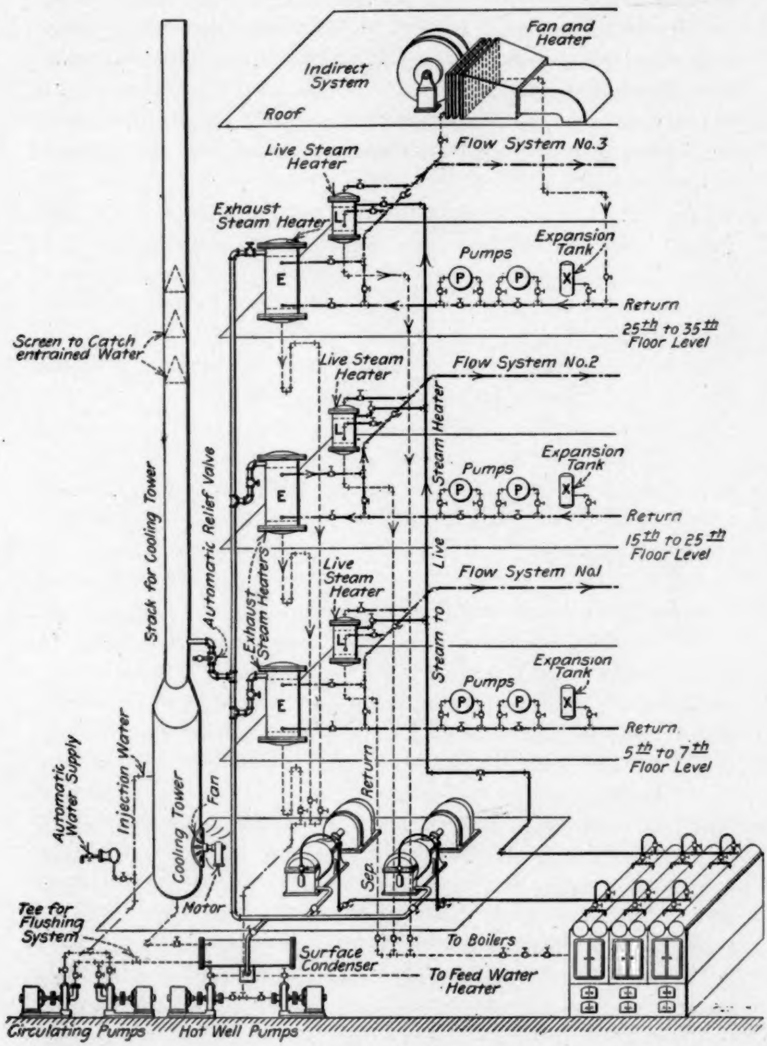


FIG. 5.—DIAGRAM OF HOT-WATER SYSTEM PROPOSED FOR HIGH BUILDINGS.

turn pipe to the various stories. Each floor is divided into one or more sections and served by a single 1½- or 1¼-in. pipe, depending on the amount of surface and floor area, and the radiators are connected in shunt or out and back into the same pipe. This pipe may be run behind a removable base, or it may be run between the sleepers carrying the finished floor. Under these conditions a 1½-in. pipe will take care of 1,000 sq. ft. of radia-

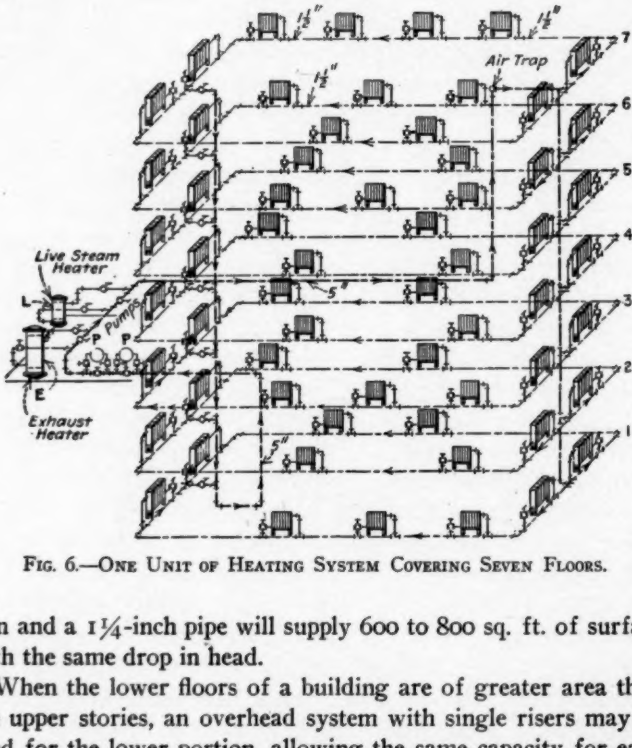


FIG. 6.—ONE UNIT OF HEATING SYSTEM COVERING SEVEN FLOORS.

tion and a 1¼-inch pipe will supply 600 to 800 sq. ft. of surface with the same drop in head.

When the lower floors of a building are of greater area than the upper stories, an overhead system with single risers may be used for the lower portion, allowing the same capacity for each riser. For the tower the scheme suggested in the diagram will prove the most economical to install. The great advantage of this system is the elimination of all risers with the expansion pieces extending into the rooms and the ugly holes at the floor and ceiling in each case. The main pipes for this layout would not be over 5 in. in diameter in any case with branches of 3 or 4 in., which is no larger than some of the single steam risers in

the ordinary building for each line of radiators. The ordinary furred spaces provided for large risers on steam systems would be eliminated and the aggregate floor space would be greater than that required for heaters and pumps of the water system.

Objection may be made to concealing the piping, and in the case of steam, due to the sudden expansion strains which do not occur on a hot-water system, the objection would be sustained. The writer designed a system for an office building in Boston where all water piping was concealed under the floors and behind the plaster, and after 12 years the system has given no trouble whatsoever. The piping, however, was thoroughly tested for expansion and pressure.

The live-steam heaters L, which are very small, connect with independent steam and return lines from the boilers; the condensation is thus returned by gravity to the boilers without pumping or releasing the pressure. Full boiler pressure may be used, and by throttling the individual returns any temperature may be maintained by allowing the condensation to back up and to cover that portion of the tube surface not required in the live-steam heater. The returns need not be over 1¼- or 1½-in. pipe. The pump capacity need not be over 20 hp.

The only precaution necessary in this system is to be sure the exhaust pipe is air-tight; this will present no difficulty if the proper material is selected before erection. Each exhaust heater is provided with a single connection with a long drop and loop of pipe not over 2 in. in diameter. The intermittent siphon action of these lines will produce a vacuum and remove the air. The lines lead to a header which is connected to the condenser. A motor-driven pump should remove this condensation to the feed-water heater, where sufficient auxiliary exhaust steam should be provided to raise its temperature to 212 deg. before returning it to the boilers.

On a job of this kind as much of the machinery should be operated electrically as possible so as to load the turbine; at the same time the units should be selected with regard to the heating load.

The cooling tower with surface condenser is shown recirculating the water for condensing purposes. A fan and motor would have to be provided and when possible, the air for the tower could be combined with the engine-room ventilation, the

hotter air being very efficient for cooling-tower purposes. A flue provided with conical wire screens should lead from the cooling tower to the extreme top of the building to carry off the vapor and prevent condensed water from falling on the roof and street. The cooling tower might be operated with natural draft in winter and the fan and motor shut down with corresponding reduction in operating expenses.

Where possible, a driven well could be provided with an air lift to furnish the water supply for the injection which is evaporated by the cooling tower. After passing through the condenser the water could be used for flushing the closets, providing an equal amount of cooler water to replace that removed, and materially assisting the action of the condenser. This arrangement would reduce the city-water bill for power and flushing purposes where well water for boiler use would be unsuited, due to impurities. By installing a turbine the use of cylinder oil is eliminated and distilled water is obtained for the boilers.

In the ordinary office building the load for lighting and elevators during the winter days is a little more than 50 per cent. of the peak. At such times the turbine would have to operate on a lower vacuum than the maximum that will furnish the proper water temperature, but the underload on the turbine with increased steam consumption per kilowatt-hour would be no added expense as it would be demanded for the heating.

When the peak comes on in the afternoon for three or four hours the heating requirements are minimum and a slightly higher vacuum can be carried than the outside-heating requirements demand without causing complaint. If the outside temperature were 35 deg., the average in the vicinity of New York, 24 in. instead of 20 in. could be carried and the full condensing power of the heating system utilized with the condenser assisting. The low-steam consumption of the turbine for overloads would make an economical arrangement for the peak load. It might be policy where the heating was in excess of the power load to install only one-half the condensing capacity, operating the machine in summer on such vacuum as would be obtained. The total steam from the power load might be such that one-half the condensing capacity with the aid of the heating system in winter at full load and vacuum would produce a fairly high vacuum at one-half load in summer.

If a condensing capacity for 6,000 lb. of steam per hour were installed for a 500-kw. unit in conjunction with the heating instead of 10,000 lb. or 500 kilowatts at 20 lb., 28 in. of vacuum would be produced on a 250-kw. load at 23 lb. per kilowatt hour. In winter this would be ample to maintain with the heating any vacuum desired at full load.

In case the building was not large enough to require a load that would warrant a condenser and a cooling tower, a fresh-air supply could be arranged on the roof with a fan and indirect stack connected to one of the hot-water systems. This would form an efficient air condenser, and the ventilation of the building could be accomplished at the same time. This would be especially desirable where the average power load was somewhat less than the heating requirements and not large enough to warrant condensing apparatus. The fan system is indicated. The time the building ventilation would be most desired would be in moderate, damp weather, when the heating system would be at low condensing capacity. In very extreme weather the fan ventilation would not be as necessary and the heating system would have greater efficiency as a condenser.

If the temperature of the air averaged about 35 deg. and the temperature of the water 155 deg. the average vacuum would be 20 in. The steam consumption of the reciprocating engine of the best type at atmosphere would be 25 lb. of steam per indicated horse-power. Allowing 20 per cent. for friction of the engine and miscellaneous losses, a kilowatt at the switchboard would require 40 lb. of steam per hour. The turbine with 500-kw. load at the switchboard and 20 in. of vacuum requires 30 lb. per kilowatt hour. This shows a saving of 10 pounds of steam per kilowatt hour.

Allowing 1,500 hr. per year (5 hr. per day for 300 days) for the peak load of 500 kw., 8 lb. of evaporation per pound of coal and \$4 per ton of 2,000 lb. for fuel, the saving would be

$$\frac{500 \times 1{,}500 \times 10}{8 \times 2{,}000} \times \$4 = \$1{,}876 \text{ per year}$$

The total cost of the cooling tower, pumps, condenser for 500 kw. at 20 lb. under full vacuum, or 10,000 lb. of steam per hour, is \$8,000 erected. The saving with this equipment installed would amount to 23.45 per cent. of its cost. The saving on a

300-kw. plant would be somewhat less in proportion, but would still leave ample margin to warrant the adoption of this type of plant. In plants under 250 kilowatts it would be better practice to use reciprocating engines compounded and operate on such vacuum as the heating system will produce with outside-weather conditions, omitting the cooling tower and condenser. From observation, it is found that generally there will be about 100 sq. ft. of heating surface to the kilowatt of power in buildings of this

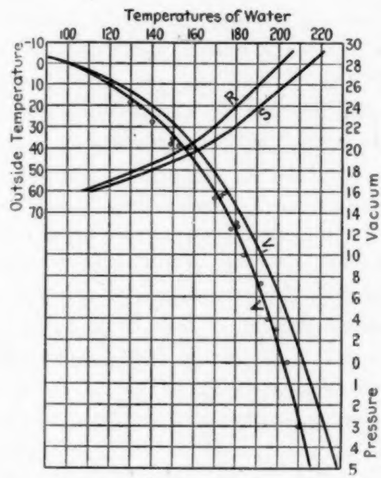


FIG. 7.—TEMPERATURE-VACUUM CURVES.

class and that the steam for the day load can easily be condensed in the heating system.

Fig. 7 shows the curves of operation of the plant of the Lackawanna railroad at its Hoboken terminal. These curves were obtained by keeping a log to determine the requirements of water temperatures for satisfactory heating, and the plant is at present operated according to this schedule. In this plant there are about 70,000 sq. ft. of radiation and the water circuit is about a mile in length.

There are several buildings. The power plant, centrally located at the end of the train shed, includes about 3,000 hp. in boilers, two large compound Ingersoll-Sergeant air compressors for furnishing air for the signals and switching system in the

yard as well as the air pressure needed to adjust the water level in the expansion tank of the heating system.

There are two Westinghouse-Parsons turbines of 500 kw. capacity each for furnishing light and power in the buildings. The power for operating the motor pump on the heating system is taken from either of these turbines. The economizer is not connected to the heating system as the plant operates 24 hr. a day and the waste heat from the gases is always economically utilized for feed purposes.

The plant is operated condensing, taking water from the North River, and the heaters and pumps for the hot-water heating system are arranged to utilize the exhaust steam under partial vacuum from either machine, as either turbine may be operated on either condenser with full vacuum by manipulating the floor-stand valves without stopping the units.

Pressure gauges on either side of the pumps show by their difference in reading the pounds pressure of friction head against which the pump is operating, and thus indicate the rapidity of circulation. The thermometer on the steam chamber of the exhaust heater shows the temperature of the reduced vacuum required for any given water temperatures indicated by the thermometers on the return header and supply main. The difference in readings of these two thermometers is the drop in temperature or the number of degrees absorbed in the heaters and extracted by the radiation. On this particular job, recording instruments are used throughout and charts are inspected daily by the chief for any unusual developments.

Curves R and S, Fig. 7, give the readings of the supply and return thermometers plotted as abscissas with the corresponding outside temperature as ordinates. Curve V_1 shows the theoretical vacuum in inches or pounds as ordinates corresponding to the supply temperature as abscissa. Curve V is the actual vacuum indicated by the thermometer on the exhaust heater with the readings plotted as ordinates and the corresponding supply-water temperatures as abscissas.

By following the outside temperature lines to their intersection with the curves R and S, the corresponding return and supply-water temperatures are found, and by following the water-temperature lines to their intersection with V_1 and V, the theoretical and actual vacuum can be read from the corresponding figures

on the right side of the chart. When the weather becomes cold the vacuum curve is steep and a slight increase in water temperature requires a correspondingly greater decrease in vacuum or increase in back pressure.

The shape of the curves R and S depend entirely on the amount of direct radiation and air supply; indirect heating may require a higher temperature of water in extreme weather and a correspondingly lower vacuum.

The amount of water circulated is found to be nearly constant for a given speed of the pump and was obtained by a recording instrument on a venturi meter placed in the water circuit. The amount at present is 3,350,000 gal. in 24 hr., or 1,158,700 lb. per hour. The amount of water and the speed of the pump are not varied, the reduction in heat transmission being accomplished entirely by changing the temperature of the circulating water and varying the vacuum. This mistake of varying the water circulation and causing a higher average water temperature has been made in a number of cases.

In extreme weather, due to the rapid decrease in vacuum, the advantages of connecting the circulating pumps in series and operating both become apparent as the increased circulation reduces the drop and the average water temperature, causing greater efficiency of transmission in the heaters and radiation and reducing steam consumption.

Table 1 gives the data. The supply and return temperatures with corresponding vacuums were taken from Fig. 7 for each 5-deg. interval of outside temperature. The vacuum in each case is the maximum that can be carried to give the proper water temperature to heat the spaces properly for any outside corresponding temperature. Column 9 shows the amount of exhaust steam available under different vacuums with a constant load of 400 kw. at the switchboard. The different rates are given in column 8, and total number of pounds of steam is found by multiplying by 400.

Column 11 is the steam consumption of a 650-hp. compound-condensing engine with 100 per cent. load and is assumed as the nearest reciprocating unit in order that its results may be compared with the turbine. The rate and total steam consumption under the different vacuums are given in column 10. By subtracting the pounds of steam available at a vacuum of 28 in.

TABLE 1.—HEAT DEMAND AND SUPPLY, HOBOKEN TERMINAL, LACKAWANNA RAILROAD.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Outside Temp. Deg. F.	Supply Therm. Deg. F.	Return Therm. Deg. F.	Dif. Temp. Deg. F.	Max. Vac.	Latent Heat.* B.t.u.	Lb. Steam per Hour.	400 Kw. Rate	Lb. Steam 400 Kw. Load	650H.P. Rate	Lb. Steam 400 Kw. 650 H.P.	Operated Red. Vac.	Surplus Steam
1	0–5	211.1	197	14.1	3 lb.	960	17,020	47	18,800	19.5	12,675	10,560	1,780
2	5–10	206	192.6	13.4	0	966	16,073	43	17,200	18.5	12,025	8,960	1,127
3	10–15	200	187.3	12.7	3″	969	15,187	41	16,400	18–	11,700	8,160	1,213
4	15–20	194.5	182.5	12	6.4″	973	14,292	38.8	15,520	17.4	11,310	7,280	1,228
5	20–25	188.3	177–	11.3	9″	977	13,402	37	14,800	17–	11,050	6,560	1,398
6	25–30	181.6	171–	10.6	11.5″	981	12,520	35.2	14,080	16.6	10,790	5,840	1,560
7	30–35	174.9	165	9.9	14″	986	11,654	33.5	13,400	16.2	10,530	5,160	1,746
8	35–40	167.8	158.5	9.3	17″	993	10,853	31.4	12,560	15.6	10,070	4,320	1,707
9	40–45	158.5	150	8.5	19.5″	1,000	9,851	29.5	11,800	15.1	9,815	3,560	1,949
10	45–50	146.6	139	7.6	22″	1,007	8,745	27.3	10,920	14.6	9,490	2,680	2,175
11	50–55	133	126.5	6.5	24.2″	1,016	7,412	25.2	10,080	14.3	9,295	1,840	2,668
12	55–60	117.5	112	5.5	26.2″	1,027	6,205	23	9,200	14	9,100	960	2,995
13					28″			20.6	8,240				

1,158,700 lb. water circulated per hour.
Column 7 = 1,158,700 X col. 4 = col. 6

*Old values used before Marks and Davis tables were adopted.

(8,240 lb.) from the quantities corresponding to the various vacuums given in column 9, column 12 is obtained. These figures indicate the cost in pounds of exhaust steam of utilizing the exhaust steam for the heating system and running the turbine under partial vacuum. Column 13 is the excess steam in any case available for further additions to the heating system; and is the difference between columns 9 and 7.

Particular attention is called to the fact that columns 7 and 9 are similar for nearly their entire length and that with a constant load by changing the vacuum the proper steam supply at the proper temperature is available to heat the circulating water of the heating system. The turbine load can be decreased slightly or more surface added to the heating system and the columns will nearly coincide. The minimum difference is 1,127 lb. and the maximum 2,995 lb., but in the latter case it may be noticed that the line goes below the requirements of the turbine on full vacuum.

Considering the flexibility of the turbine for change in load and vacuum, ease of operation, floor space, and slightly better steam consumption for overloads and full vacuum, the economy of the turbine is fully as good, if not better, than the reciprocating engine for exhaust hot-water heating with partial vacuum on units of over 250 kw. Engineers in general have been reluctant to reduce the vacuum on large turbine units on account of the rapid increase in steam consumption, but a study of the table will show the advantages to be derived from this practice. In making the comparison of the turbine and reciprocating engine the number of hours' operation (about 1,500) in summer when no heating is required should be taken into account when the steam consumption of the reciprocating engine under the same load and full vacuum will be greater than that of the turbine.

The data in regard to the use of the steam for heating in this plant are the result of many months' operation and are absolutely reliable. They show that the heating steam with all surface turned on varies from 6,205 lb. at 60 deg. outside temperature to 17,000 lb. in 0 to 5 deg. weather outside. This shows the main saving in a hot-water plant whether exhaust or live steam is used to heat the water. It also explains why many mills use live steam for heating at high pressure. The cost of the plant and comparatively few hours of exhaust heating (1,500 as against 3,500 hr.

of night and holiday heating) makes the proposition one to be considered.

The decrease in steam consumption on the turbine with a 400-kw. load between no vacuum and full vacuum is, according to

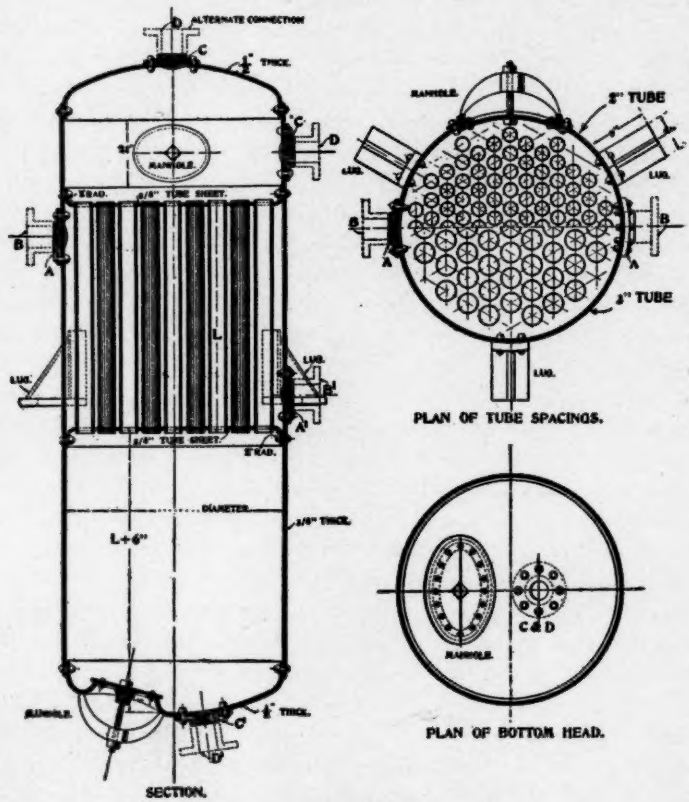


FIG. 8.—DETAILS OF LIVE STEAM WATER HEATER.

Table 1, 10,560 lb., and the change in steam requirements on the heating system between 0 and 60 deg. is 10,815 lb. per hour. This shows nearly the same range. It should not be lost sight of that the heating system acts as a condenser, taking a portion of the regular condensing load and reducing the injection water required in the winter time. The curves also make it apparent why the condenser cannot be used as an exhaust heater where a

turbine is operated under partial vacuum. This opens up a field for cooling towers and air condensers where heretofore the exhaust heating problem seven months in the year has eliminated them from consideration, especially for large commercial buildings in cities.

Although a plant may be operated 24 hr. a day the writer has used the data in Table 2 to show how the steam consumption could be determined in a plant when the heating, nights, Sundays and holidays, is operated on live steam due to the main engines being inoperative. This table is very useful in determining the total steam on any heating plant in the New York district. A like chart can be made for any district by obtaining the record of temperature, maximum, minimum and average from the United States Weather Bureau office in that district for each day and month of the heating season. These are plotted on regular thermometer charts, making a day operation of 10 hr. and night operation of 14 hr., and indicating holidays and Sundays by washed spaces of heavier or lighter color. The weather clerk can usually give a typical daily curve for that district and the minimum and maximum temperatures occur generally at the same hour each day. These temperature charts when pasted together give a continuous curve of temperature for the month with the night and day periods for week days, Sundays and holidays clearly indicated. A heavy line may then be drawn through the average for each 5- or 7-hr. period. The total number of hours for each 10-degree period of outside temperature can be obtained and tabulated for use as in Table 2.

In Table 2, A shows the engines would be operated in the ordinary industrial plant and exhaust steam available 1,545 hr. or 30.68 per cent. of the time and shut down 3,491 hr. or 69.32 per cent., when live steam would have to be used for heating. In case night operation or two shifts a day were under discussion the night periods would amount to B, or 2,142 hr. additional.

There are cases where it has been recommended to take steam for heating and other purposes from the receiver between the cylinders of a reciprocating engine and from a turbine between the stages. This has resulted in a number of fallacies as to economy. The governor on a large engine will not regulate for a greater range in total steam consumption than the equivalent of no vacuum and full vacuum, or from 25 to 30 per cent. and

TABLE 2.—NUMBER OF HOURS FOR EACH 10 DEGREE PERIOD OF TEMPERATURE FROM 0 TO 60 DEGREES, NEW YORK DISTRICT.

Month	Week Days											
	"A" Days. 7 a.m. to 5 p.m.						"B" Nights. 5 p.m. to 7 a.m.					
	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°
Oct.				5	35	85					56	140
Nov				90	105	20				168	105	14
Dec		25	100	80	20			70	175	28	14	
Jan		10	60	135	25		28	14	84	161	14	
Feb	10	15	40	95	35	15	14	28	70	105	28	21
Mar			5	90	90	55			21	168	84	49
April				5	35	155				14	133	154
May					5	100					28	154
Total	10	50	205	500	350	430	42	112	350	644	462	532
Per Cent.	0.19	0.99	4.07	9.94	6.95	8.54	0.83	2.23	6.95	12.8	9.2	10.6
Total	1545 hours 30.68 per cent.						2142 hours 42.6 per cent.					

Month	Holidays, Sundays											
	"C" Days. 7 a.m. to 5 p.m.						"D" Nights. 5 p.m. to 7 a.m.					
	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°
Oct.					10	30				28	21	63
Nov				35	45					119	14	
Dec		15	45	10	15			56	70	14		
Jan		5	25	35	15			7	10	56		
Feb		5	40	25			14	·14	84		14	
Mar				5	35	15					42	70-
April					10	40					70	42
May						25					28	28
Total		25	110	110	130	110	14	77	164	217	189	203
Per Cent.		0.5	2.19	2.19	2.58	2.19	0.27	1.53	3.26	4.3	3.76	4.04
Total	485 hours 9.65 per cent.						864 hours 17.16 per cent.					
	3491 hours 69.32 per cent.											

generally less. When the pressure on the receiver of a reciprocating engine is lowered sufficiently to require a reducing-valve connection, the steam may be taken from the main steam pipe with as good results. The turbine will likewise show an increase in steam consumption per kilowatt when the stages are tapped that will indicate a reduced economy from the practice. It can be done, however, if less than 10 or 15 per cent. of the steam required to operate the machine is taken in this manner. If the turbine or engine is especially designed with high-pressure parts of greater capacity for this work the machine will be uneconomical if at any time the conditions are reversed and the steam is not needed in the heating system. In any case, it will be the consensus of opinion that taking the steam in the manner indicated between the engine and condenser is far more economical than tapping the stages of the turbine or receiver of the engine.

Hot-water heating would be especially advantageous in connection with low-pressure turbines and reciprocating engines, using cooling towers in case injection water was not available. The study shows that over 50 per cent. of the exhaust steam required in zero weather for heating would be available for power 80 per cent. of the time on the low-pressure turbine.

One problem that was studied contemplated the constant load of 400 kw., but on the plant in question the load is variable, ranging from 300 kw. at noon to 700 kw. at night for 24 hr. When a variable load is under consideration, a chart should be worked out for the heating in pounds of steam, and one for the daily load, showing the average hourly variations for 24 hr. With pounds of steam as ordinates and hours as abscissas, the curves of steam consumption for each 5 in. of vacuum between full vacuum and atmosphere should be plotted for the engine or turbine for the average daily load, showing the hourly variations. From these charts one should be constructed for each 10-deg. period from 0 to 60 deg. with pounds of steam as ordinates and hours as abscissas. Each chart will have four curves: the typical curve of temperature outside, showing the hourly variation; the turbine steam consumption at full vacuum; the heating curve in pounds of steam, and the curve of actual steam consumption of the turbine at the hourly loads.

By dividing the hours, Table 2, by 24, the number of days can be obtained for each 10-deg. period of temperature. When the

areas between the curves on each of the six charts are determined and multiplied by the number of days in each case, the heating, excess steam and cost of reducing vacuum can be determined for the season.

When the load is at the peak, one machine may not carry it at reduced vacuum. It is economical then to turn the turbine into the condenser with full vacuum, especially when the peak is of only two or three hours' duration. The circulating pump will continue to operate but no heat will enter the system. Before and after the peak occurs the vacuum may be lowered and 10 deg. higher temperature than the weather requirements demand may be carried on the water system. By this arrangement starting up a second machine is avoided and a great waste of steam due to high load and low vacuum is prevented.

Heating and power curves together with the steam consumption are worked out in charts A, B, C, D, E, F and G, and Tables 1, 2 and 4, for the entire heating season with the variable power load as it actually occurs.

One column in Table 1 gives heating requirements in pounds of steam for each condition of outside temperature with the maximum vacuum necessary to produce the water temperatures and maintain a constant temperature of 70 deg. in the room with the proportion of heating surface installed in this particular case. These records are plotted from recording thermometer charts covering a considerable period of time.

Chart A, Fig. 9, is the steam consumption of a 500-kw. turbine unit under different loads and degrees of vacuum with steam at 150 lb. gauge and 15 deg. superheat.

Chart B, Fig. 10, is the steam consumption for the hourly load under different degrees of vacuum at the switchboard with all curves included. The load varies from 200 kw. to 750 kw. with two peaks, one at 5 p. m. and 7 a. m. The water from the condenser was weighed and load and vacuum noted. These variations in load are handled entirely with two machines, and if the load was considerably increased the charts show that the steam consumption due to reduction in vacuum would be very little greater as the machines are underloaded a portion of the time. The hourly load is plotted in kilowatts at the bottom of chart B and the average hourly load is 480 kw. per hour. All areas were measured by a planimeter.

TABLE 4.—DATA FOR CURVES A, B, C, D, E, F, G AND H.

		Curve H.		Curve T.		T—(H or T')		Average Ordinates			
Outside Temp.	Days	Heating Per Day	Total Steam Heating	Steam Power & Heat Per Day	Total Steam Heat & Power	Excess Steam	Total Excess Steam	Power and Heating	Heating	Excess	Rate per K. W.
0°–10°	2.75	374500	1,029,875	440000	1,210,000	65,600	180,400	18,333	15604	2733	38.2
10 –20°	11–	353600	3,889,600	428800	4,766,800	75,200	827,200	17,856	14733	3133	37.2
20 –30°	34.5	314240	10,841,280	385600	13,303,200	69,120	2,384,640	16,070	13100	2900	33.5
30 –40°	61.3	274400	16,820,720	348800	21,381,440	74,400	4,560,720	14,533	11433	3100	30.3
40 –50°	47.12	224640	10,585,040	307520	14,490,342	63,200	2,977,984	12,813	9360	2633	26.7
50 –60°	53.12	157120	8,346,214	259200	13,768,700	27,840	147,886	10,800	6550	1160	22.7
Totals	209.79		51,512,729		68,870,482		11,078,830				

Average Power, 480 K.W.
228,800 # per 24 hours. Curve T'.
20 # per K.W. @ 28" Vacuum.

For 209.79 Days × 480 K.W. × 24 = 2,416,800 K. W. hrs.

$$\frac{68,870,482}{2,416,800} = 28.5 \text{ \# P.K.W. Average rate.}$$

The double curve of the power show when two machines are operated at the peak, one under reduced vacuum for heating and

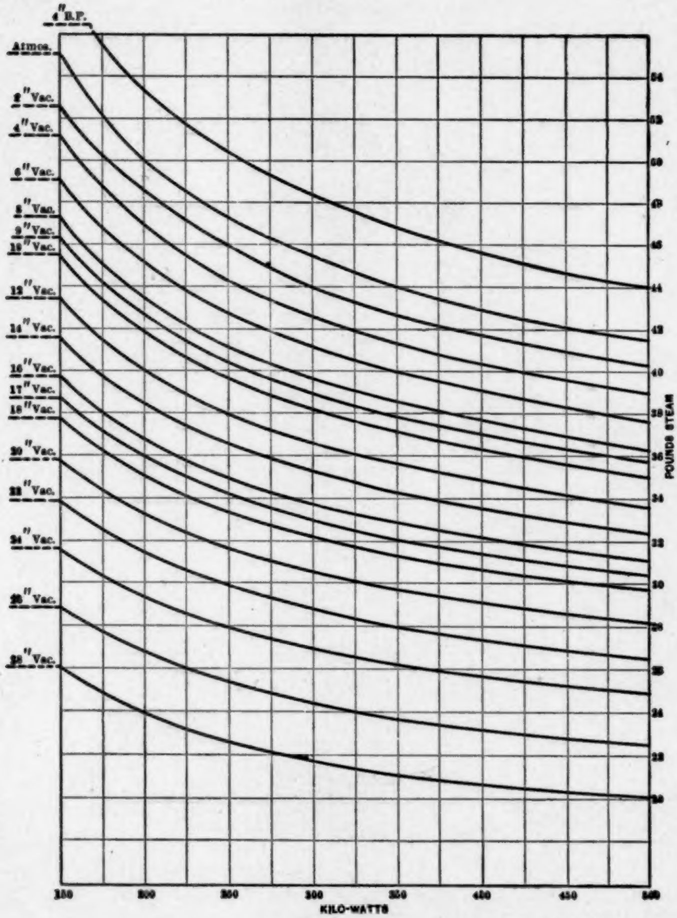


FIG. 9.—STEAM CONSUMPTION CURVES OF 500-KW. TURBINE; STEAM 150 LB. AT THROTTLE; SUPERHEAT 15 DEG.

one at 28 in. of vacuum. The limit the machine will carry at no vacuum is 375 kw., and 950 kw. has been carried a short time at 28 in. vacuum with one machine. A load of 375 kw. just balances the heating load in amount of steam and temperature by simply changing the vacuum as described.

Up to 30 to 40 deg. outside (Chart F) it is most economical to operate two machines from 4 p. m. to 2 a. m., but for Charts C and H it is necessary only to operate two machines from 4 p. m. to 10 p. m. Except in extreme weather at low vacuums the load is carried at all times with one machine or until the

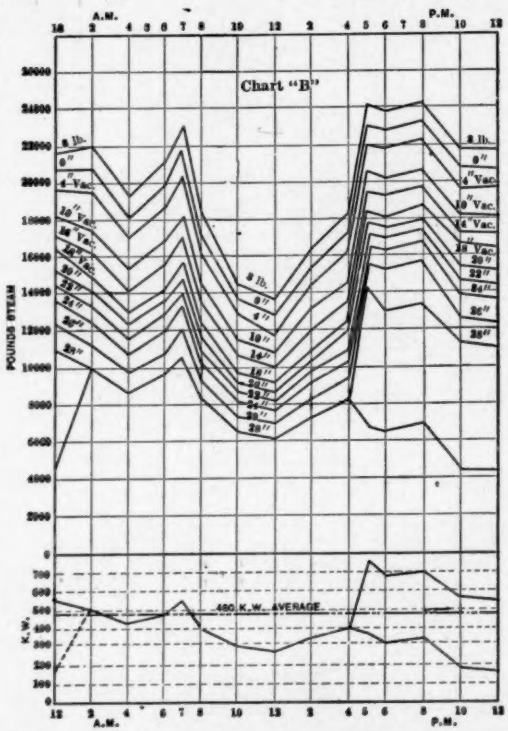


FIG. 10.—STEAM CONSUMPTION ACCORDING TO LOAD AND EXHAUST PRESSURE.

vacuum gets below 10 in. In working out the charts the minimum steam consumption will be shown by operating the two machines as indicated.

Curve T^1 is the turbine steam consumption under the characteristic load at 28 in. of vacuum on each chart. Curve H is the curve of heating from the curve of outside temperature at the bottom of each chart for a typical day for each period of 19 deg. range of outside temperature. The number of days for each period are taken from Table 2 by dividing the total hours for

each period by 24. Curve T on each chart is the steam consumption of the turbine under the hourly load and vacuum which will produce the proper water temperature for curve H.

At the peaks the vacuum has been decreased slightly so as to improve the steam consumption. Curve T^1 at 28 in. of vacuum encloses the area to the base line with the steam consumption required for power if no heating were required. Curve H likewise encloses the area for the hot-water system, whether live steam or exhaust is used. Curve T would be the requirements for heating

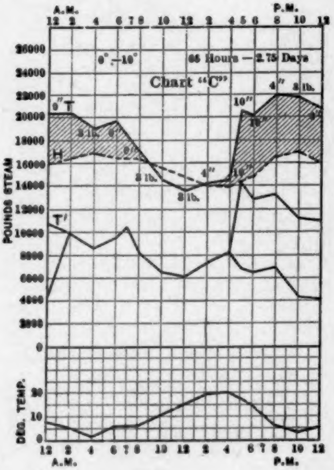


FIG. 11.

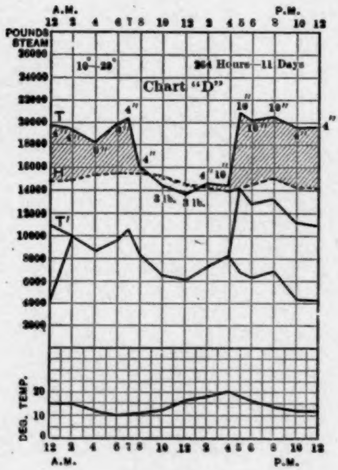


FIG. 12.

and power combined for each typical day and power load. The saving is the excess steam areas between T and H or T^1, as the case may be, deducted from the area enclosed by T^1. All areas were read by a planimeter, and the average ordinates and results are tabulated in Table 4 and graphically in Chart I. It is seen that in some cases H is greater than T^1 and in others, viz., for the high temperatures out of doors, T^1 is greater than H. In any case, the heating and power at full vacuum are fixed by requirements regardless of other conditions.

When less power is generated than the balanced load, the vacuum will have to be reduced, to increase the quantity of steam to maintain a proper water temperature on the heating system. It will not pay to carry normal vacuum for that outside tempera-

ture and operate the live-steam heater to furnish the additional heat, although the apparatus is arranged so that this could be done.

At noon in most cases, the vacuum is reduced below normal to furnish steam for heating on account of light load. Where this occurs on a vacuum system, the reducing valve would have to open to supply live steam to keep the pressure from dropping too low. The curves show that this arrangement would be ideal from an operating standpoint for a high office building and

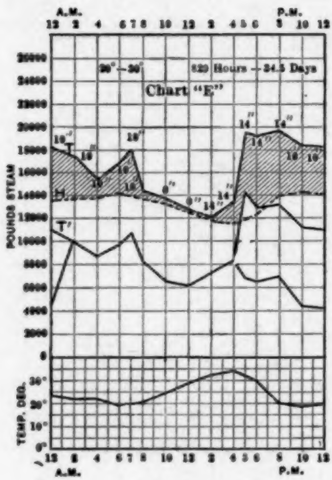


FIG. 13.

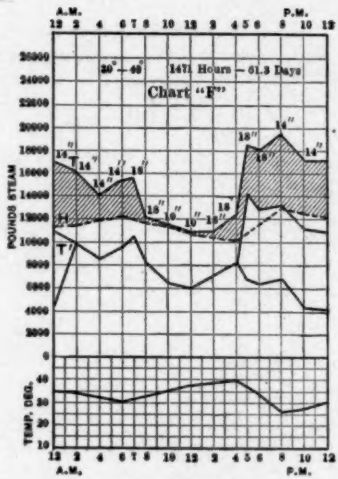


FIG. 14.

hotels where the heating load at times exceeds the power load. One turbine unit could be operated on the heating of a size to just balance the requirements of the heating system, and when the machine is under loaded the decreased vacuum would be no additional expense.

When the turbine load can be balanced against the heating, the excess steam on the charts will disappear. In this case 375 kw. just balances the heating at all outside temperatures. This would also eliminate the different sized units to take care of the variations in load so as to obtain an economical steam consumption as in case of reciprocating engines.

As the summer load is considerably less than the winter load, condenser capacity to the extent only of the power installed in

addition to that which will balance the heating need be furnished, utilizing the vacuum that this condensing capacity will produce in summer under the reduced conditions of load. This will cut down the first cost of installation without seriously interfering with the economy. It is a question to be determined in each particular case. The only reason advanced for not operating condensing engines for large office buildings has been the requirements of the vacuum heating system or possibly the excess of heating over power requirements. With the hot-water system as

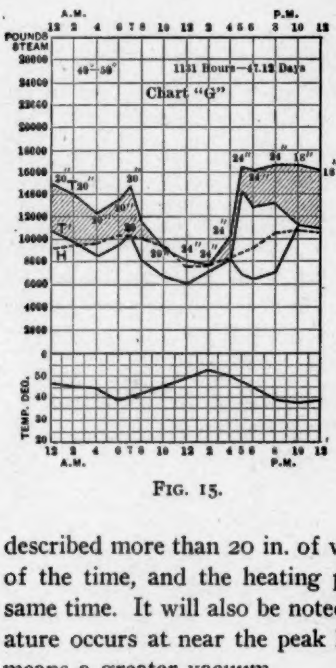


FIG. 15.

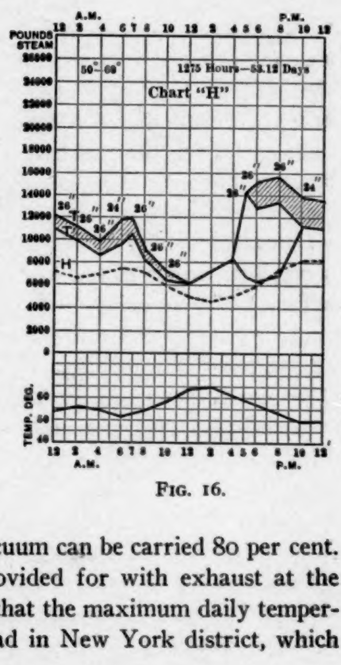


FIG. 16.

described more than 20 in. of vacuum can be carried 80 per cent. of the time, and the heating provided for with exhaust at the same time. It will also be noted that the maximum daily temperature occurs at near the peak load in New York district, which means a greater vacuum.

The operation of the plant is simple, the temperature of the return water being regulated by adjusting the valve x, Fig. 1, at intervals of two hours as the load or outside temperature changes. The curves and resulting vacuums are entirely the result of manipulating this one valve, and the hourly load at that period. The second turbine is started when necessary and the same condenser handles both machines, one exhausting direct to the condenser under full vacuum and the other to the hot-water system under

reduced vacuum. Attention is called to the following facts demonstrated by Table 4 and the charts:

The range in heating curves shows 100 per cent. range between the 0 to 10 deg. condition and the 50 to 60 deg. condition. This range is impossible on a steam system except with automatic heat control kept in operating order. If the 0 to 10 deg. condition, and 347,500 lb. of steam per day are taken for the steam consumption minimum for a vacuum system at 212 deg., the total steam consumption for 209.79 days would be 78,566,000 lb. against 51,512,729 lb., or a difference in favor of the hot water of 27,043,271 lb., which at 20 cents per 1,000 lb. would be a saving of $5,410 per year, or 35.4 per cent. saving. This shows the hot-water saving where there is no power to be considered and live steam is utilized for heating in either case.

If 45 lb. per kilowatt hour is used for the steam consumption at atmosphere at the switchboard and 209.79 hours, the steam for power would be for 480 kw. average load, 108,756,000 lb., which at 20 cents is $21,751. This does not allow for any live steam for periods of low load to keep up pressure on the heating system and preventing air leaks. The cost of power and heating combined on the hot-water system is 68,870,482 lb. at 20 cents = $3,774.09. This represents a saving of $7,977, or 37 per cent. The cost of operating the hot-water system on live steam and condensing the engines under full vacuum would be 51,512,730 + 48,000,000 = 99,512,730 lb., which at 20 cents amounts to $19,903. Also, 99,512,730 lb. — 68,870,482 lb. = 30,642,248 lb., which at 20 cents is $6,130 per heating season, or 31 per cent. The saving effected by utilizing the engine exhaust under partial vacuum would be with reference to the heating the excess steam deducted from the steam under full vacuum or 48,000,000 — 11,078,830 = 36,921,170 lb., which at 20 cents is $7,384, or 70 per cent.

In case a lower cost of coal is desired than assumed, a proper proportion will determine the saving. This saving is figured in fuel at $3.60 per ton and does not include city water saved in condensation or wear and tear on extra boilers and apparatus to burn the fuel. The turbine also requires no cylinder oil, which is an item of expense. This system, if properly designed, can be installed for the same cost nearly as the low-pressure steam system if all specialties are included. The covering for risers

within the building required on steam can be omitted, reducing the temperature of the water within the system by the amount corresponding. Automatic heat control can be omitted as a constant temperature in the rooms can be maintained by regulating the temperature of the water at the plant. These items of expense will more than balance the cost of the heaters and pumps. In any case, the saving capitalized would warrant a considerable expenditure in addition in favor of the water system. These

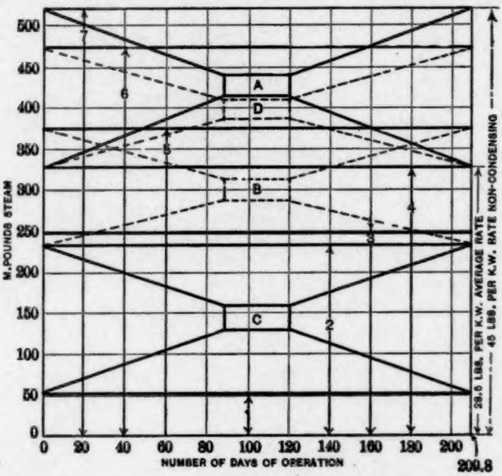


FIG. 17.—CHART I, SHOWING GRAPHICALLY THE FIGURES OF TABLE 4; COAL, $3.60 PER TON OF 2000 LB.; 9 LB. EVAPORATION; STEAM, 20C. PER 1000 LB.

1. Excess Steam or Cost of Heating Hot-Water Partial Vacuum....11,078,830 at 20c. per M, $2,216
2. Cost, 2,416,800 k. w. hr. at full vacuum, 28 in., at 20 lb.......48,000,000 at 20c. per M, 9,600
3. Cost hot-water heating on live steam for season.............51,512,730 at 20c. per M, 10,305
4. Cost heating and power under partial vacuum at 28.5 lb. per k. w. hr....68,870,480 at 20c. per M, 13,774
5. Cost of heating steam at 200 deg.; average, 374500 (lb.) x 209.79 (days)....78,566,000 at 20c. per M, 15,713
6. Cost hot water heating live steam power under full vacuum 28 in. (2x3)....99,512,730 at 20c. per M, 19,903
7. Cost of power at 45 lb. per k. w. hr at switchboard...........108,756,000 at 20c. per M, 21,751

A—L. P. exhaust vs. hot water (7—4), $21,751—$13,774=$7,977, or 37 per cent.

B—L. P. steam vs. hot water live steam. (5—3), $15,713—$10,305=$5,408, or 35 per cent.

C—Saving on hot water ref. to heating. $\frac{(2-1)}{3}$ $\frac{9600-2216}{10305}=\frac{7384}{10305}$=72 per cent.

D—Saving on hot water on total heating and power vs. live steam and full vacuum: (6—4), $19,903—$13,774=$6,129, or 31 per cent.

savings can be taken as nearly standard percentages for any condition. Chart I, Fig. 16, gives the results graphically.

The author is indebted to Mr. W. E. Van Patten of the Hoboken terminal of the Delaware, Lackawanna & Western Railroad for the records of the company's plant.

DISCUSSION.

M. S. Cooley (by letter): In reading over the paper by Mr. Evans on vacuum hot-water heating, I notice his rigid separation of the exhaust heater and the condenser. While it is evident that we need one heater and one condenser, at times when the demands of the heating system are not equal to the amount of heat in the exhaust, I see no reason why these two appliances may not be made identical, and so piped that either may be used either as condenser or exhaust steam heater. Thus in the case cited on page 237, he need have only a 6,000 lb. condenser and in summer use his exhaust heater in conjunction and be able to operate at full load or even overload on his 500 kw. turbine running on full vacuum in lieu of only about half load as with no change over connections for his exhaust steam heater. In the installation of State, War and Navy Buildings this is successfully done.

Mr. Evans (by letter): I note Mr. Cooley's statement about combining the exhaust heater with the condenser on a vacuum hot water heating plant.

The conditions of power and heating load on the State, War and Navy Buildings are entirely different from the plant described in the paper on vacuum hot water heating.

It might occur on small installations when the amount of vacuum on the machine operated on the heating system was of secondary importance, or when the exhaust was inadequate, a large portion of the time when this might be done.

The Hoboken plant is 3,000 h. p. capacity, with two turbines, aggregating under full vacuum a maximum load capacity of 1,500 kw., and therefore is hardly a comparison with the plant cited by Mr. Cooley.

A few very good reasons for not following Mr. Cooley's suggestions are as follows:

1. It is desirous to fix the vacuum on the machine operated on the heating system at the maximum point at all times on account of the turbine steam consumption.

2. The multiplicity of pipe connections of large size to make the condenser interchangeable as an exhaust heater would probably cost more than a separate exhaust heater which can be built entirely of iron. The job in question would require 20-

in. steam connections, and 10-in. water connections with several valves of the same size.

3. The turbine should be placed as close to the condenser as possible on account of air leaks which would enhance this difficulty with a multiplicity of connections.

4. The conditions of operation, range of temperatures, square feet of surface required, are entirely different in the exhaust heater than on a surface condenser; the capacities as well may be entirely different. Also the iron tube heater cannot be used as a condenser.

5. Finally a condensing turbine plant should have its arrangement of economical conditions for operating under full vacuum interfered with as little as possible when a vacuum hot water heating system is installed.

6. The conditions cited on page 237 referred to the use of hot water for high buildings. The condenser capacity was reduced due to the reduced power load in summer over winter.

CCLXXXI.

VENTILATION OF A STEAM LAUNDRY

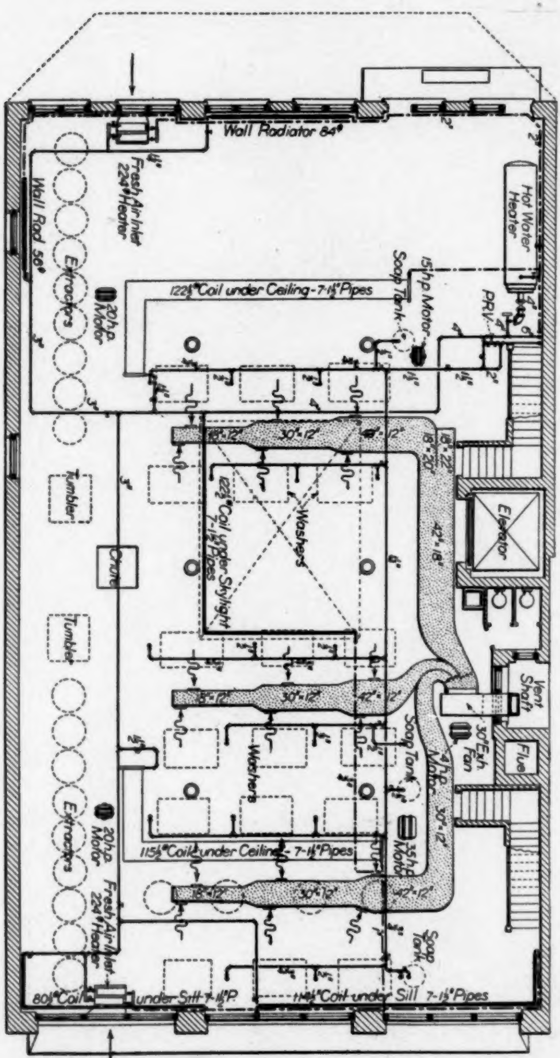
BY A. M. FELDMAN

In the report of the Commissioner of Labor of New York State for 1908, 1909 and 1910, there is given a table showing the condition of air as found by the factory inspectors in various industries, among which are tabulated figures of conditions in laundries. Excluding all cases where the outdoor temperature was over 70 deg., the report states that there was not a single laundry visited by the inspectors where the temperature was found to be 72 deg., or less. Seven laundries had temperatures of 73 deg. to 79 deg., and seven 80 deg., or over. The relative humidity in some of those laundries was over 70 per cent.

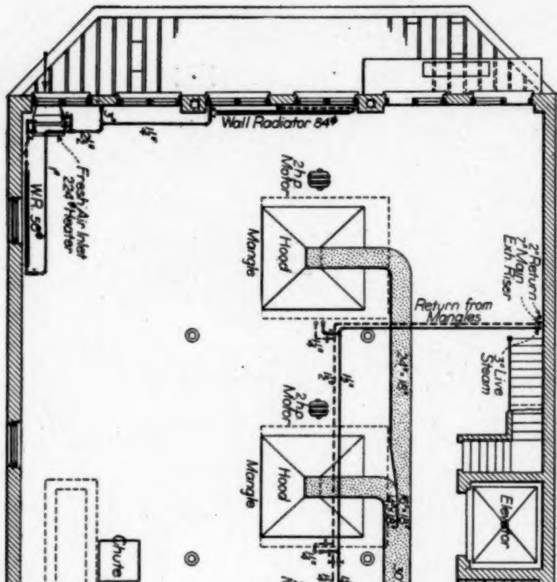
The laundry described in this paper was designed by the author last spring for the New York Barber Towel Supply & Steam Laundry Co., at East 32nd Street, New York. It consists of three stories and basement, each 88 ft. long by 51 ft. wide, while the first floor is 95 ft. long. The height of the ceilings are 14, 13 and 12 ft., respectively; the cubic contents are 67,830, 58,340 and 53,850 cu. ft., respectively. The soiled towels and napkins are taken up on an elevator to the top floor where they are washed in revolving washers; then the moisture is removed from them in extractors; then they are delivered through chutes to the two lower floors where they are passed through steam mangles to be dried and ironed.

The building is exposed north and south with large glass surfaces. Coils and wall radiation are provided under the windows to compensate for the heat losses through these areas. To remove the steam rising from the washers on the top floor and steam and excessive heat from the mangles on the two lower floors, each floor is provided with a multivane exhaust fan and a system of ducts and hoods over the mangles.

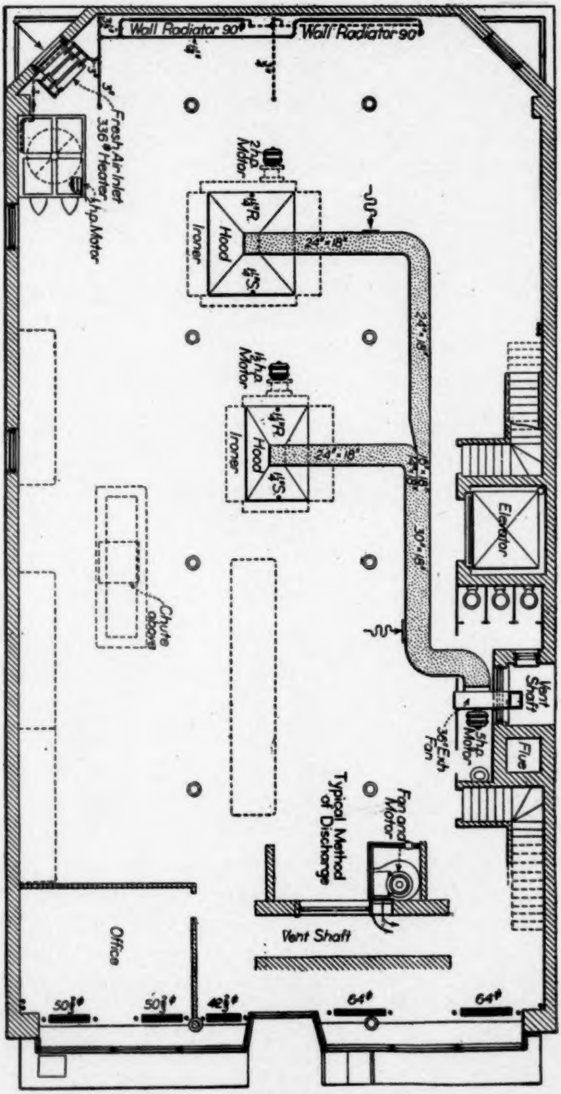
Fresh air is supplied through the lower halves of two win-



THIRD FLOOR PLAN OF STEAM LAUNDRY.



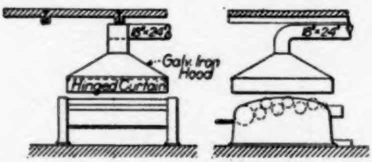
SECOND FLOOR PLAN OF STEAM LAUNDRY.



FIRST FLOOR PLAN OF STEAM LAUNDRY.

dows in opposite walls on each floor of the building, where Vento indirect radiators are installed to temper the air. The free area of each stack is 6.5 sq. ft. The system provides a uniform distribution of fresh air without any drafts. The air is drawn toward the hoods by exhaust fans. The workers at the mangles in hot summer days feel a breeze, as the fresh air is moving over them toward the hoods. There are no hoods provided over the washers on the top floor, for fear of interfering with the cold and hot water and steam pipes. The ducts have a number of wire screened openings.

The fans on the first and second floors are 36-in. multivane type, running 350 r.p.m. with a rated capacity of about 750,000 cu. ft. of air per hour. On the top floor the fan is a 30-in. multivane, running 450 r.p.m. with a rated capacity of about 570,-



ARRANGEMENT OF HOODS AND VENTILATING DUCTS FOR MANGLES.

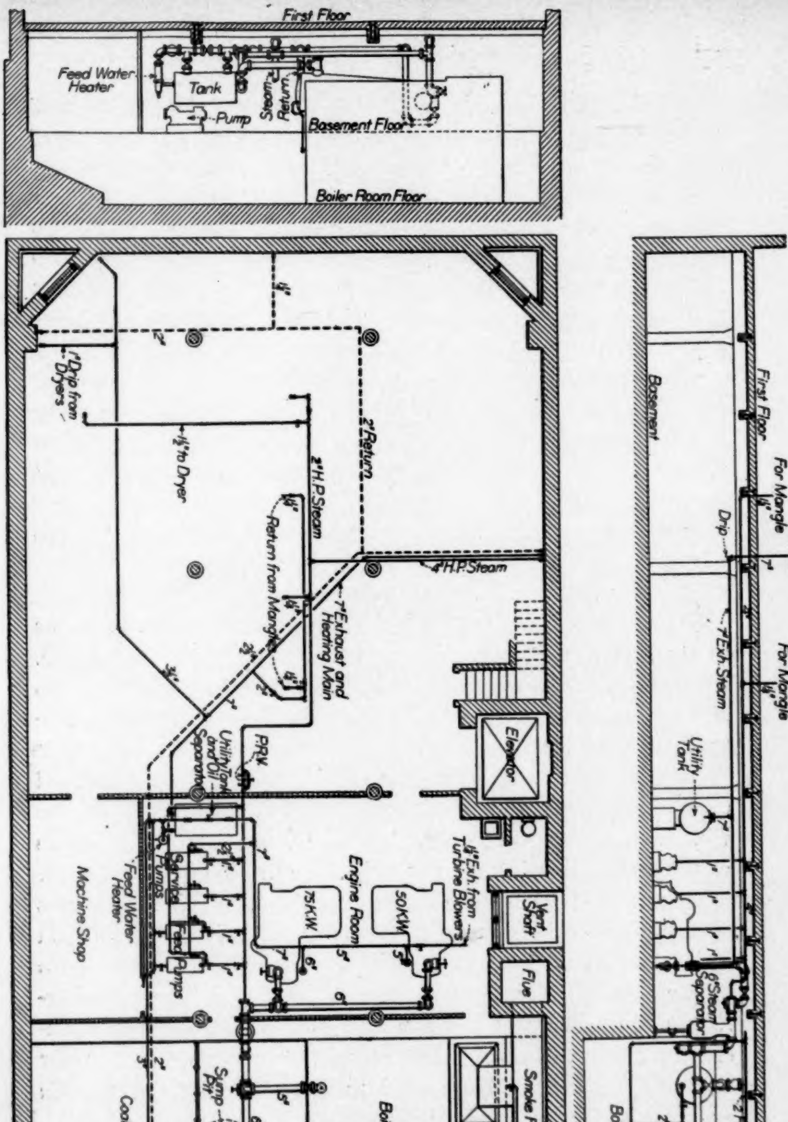
000 cu. ft. of air per hour. Only in very cold weather is the speed of the fans reduced; otherwise they are running at full speed.

The following tests carried on with a sling psychrometer may be of interest:

On December 4, 1911, with an outdoor temperature of 20 deg., the average temperature on the first floor was 64 deg. with a relative humidity of 47 per cent.; on the second floor the average temperature and relative humidity were 70 deg. and 54 per cent., respectively. A vestibule was erected at the entrance door to the first floor after December 4, the lack of it accounting for the low temperatures on first floor found on that date.

On December 18, 1911, with an outdoor temperature of 37 deg., the average temperature and relative humidity on the first floor were 68½ deg. and 54 per cent., respectively; on the second floor, 70 deg. and 46 per cent.

On January 22, 1912, on the top floor, where the washers and extractors are located, notwithstanding constantly rising vapor, open gutters full of water, and the entire floor wet, the



PLAN AND ELEVATIONS OF BASEMENT OF STEAM LAUNDRY.

average temperature was 64½ deg. and the average humidity 74½ per cent. On the second floor, the average temperature was 70 deg. and the average relative humidity, 35 per cent.; on the first floor the average temperature was 67½ deg. and the relative humidity 37½ per cent. The outdoor temperature was 42 deg. During lunch hour when the fans were not in operation the temperature on the second floor rose to 75½ deg. with a relative humidity of 24½ per cent., and dropped again to the above condition after a half hour's operation of the fan.

It is the consensus of opinion of the owners and all those who visit the establishment that it is the best ventilated laundry in the City of New York. The result obtained with the ventilating system is due to the fact that the rising steam and heat from the mangle cylinders are removed at the very source where they are generated and fresh tempered air is admitted at opposite ends of the lofts. There are 40 girl workers on the first floor, 60 on the second, and 15 men on the top floor.

The building has its own isolated power plant for the supply of steam, hot and cold water, and current for light and power. The plant occupies a part of the basement floor. It contains two 200 h.p. water-tube boilers equipped with individual undergrate turbine blowers to assist the draft and to allow No. 2 buckwheat coal to be burned. There are two high-speed direct connected engine-driven generators, of 50 and 75 kw. capacity, of double voltage of 230 and 115 volts. The motors are operating on 230 volts and the lighting on 115 volts. The average load is 50 kw.

It may be of interest to note that the traps of the mangles discharge into the exhaust and low-pressure heating main, in which part of the high pressure condensation flashes into steam at the relatively low temperature. The average pressure carried on the boiler is 100 to 110 lbs. For the mangles and washers, the pressure is reduced to about 75 to 80 lb. The author may add that for the five mangles and 20 washers a 4-in. main was provided, steam being reduced into it through a 2-in. Cash pressure reducing valve, and both the size of the main and that of the reducing valve have proved to be proper.

DISCUSSION.

The President: That is a very interesting paper in itself, but still more interesting from the point of view of our Society.

It is another illustration of the fact that our Society's members are willing to come forward and give us the benefit of their actual practice and experience as freely as Mr. Feldman has now done, and as Mr. S. R. Lewis did at the Chicago summer meeting. We ought to congratulate ourselves that this society is one in which its members show such a willing spirit. In connection with the discussion of this paper, which includes the subject of ventilation, I am going to ask Mr. Whitten to describe what he was not able to describe yesterday, the methods employed by the committee on schoolroom ventilation, of which he and Mr. Cooper are members, and then we will open the discussion on ventilation, so as to include the subjects that were discussed yesterday, for a short period of time.

Mr. Ingalls: I would like to inquire of Mr. Feldman as to how he introduces his fresh air into this laundry.

Mr. Feldman: Air is pulled through the window in the rear of the building. I did not provide any opening in front because plenty of air was coming through the door. On the second and third floors, fresh air is admitted through a front and a rear window, as shown on the plans.

Mr. Ingalls: Simply to draw the air in?

Mr. Feldman: The air is just drawn in. When you exhaust the room, air is bound to come in. It is delightful in summer because the helpers feel the slight draft coming toward them.

On the first and second floors one cannot detect any laundry odors.

Mr. Ingalls: What temperature do you figure on the entering air?

Mr. Feldman: I wanted it to come in at about 70 to 75 deg. I stood with my thermometer about 3 ft. away from the Ventos and found it to be 75 deg.

The President: May I ask for general information how the building stands as regards the compass?

Mr. Feldman: North and South; there are windows in the front and rear.

Mr. President: Is the intake on the southerly side then?

Mr. Feldman: On the second and third floors, both southerly and northerly sides, and on the first floor is only on the south, because on the north is the entrance door.

CCLXXXII.

EFFICIENCY OF LABOR IN THE HEATING INDUSTRY.

BY NORMAN A. HILL.

In the matter of labor efficiency investigations in the heating industry it is quite possible that some members of the Society present, and others not here to-day, have done a great deal more in this field than I have. In investigating the efficiency of the direct labor element in a number of factories during the past two years, I have included some observations on steam fitters' work.

On the general question of efficiency of labor, I will refer you to the works of F. W. Taylor, Harrington Emerson, H. L. Gantt, C. R. Day and J. B. Griffith; and the relevant comment on their works made in "System," "New England Contractor," "Factory," "The Iron Age," "Heating and Ventilating Magazine," "Engineering Magazine" and "Industrial Engineering."

In connection with this work, the first item for the consulting or contracting engineer in the heating business to consider is the plan of business conduct.

After perfecting a plan and organization, which we will consider as a corporation, it must perfect an organization, consisting of two radically different forces, namely, the line and the staff. Under the head of "line" may be mentioned the superintendent, under him the foreman and steam fitters in charge. Under the staff organization for a contractor or engineer, we find the executive officers followed up by subordinates: the sales or contract department, the accounting and cost department, the purchasing or material department.

Under "staff analysis" we find the following conditions in either a contracting or engineering business: that the men in control possess the executive positions, and therefore, control the policy of the organization and its matters of routine. It

is up to their best judgment to conduct the business as they see fit. It is not the purpose of these few remarks on efficiency as applied to the heating industry, to comment on the conduct of the office organization of either heating engineers or contractors.

Referring to the topic under discussion, namely, the efficiency of labor in connection with the heating industry as a line proposition, particularly for the contractor, an analysis of the worker may be outlined as follows:

(1) Men. The Nationality of the worker must be taken into consideration. If he is native born, the problem of handling him under scientific management is usually simple. If he is foreign born, the problem has certain complications. In any case, the habits of the worker must be considered, as to his industry, skill, temperament, character and sobriety. In case he is a member of a local labor union under any plan of scientific management, he must be handled with tact and discretion.

(2) As to the machine, it must, in the first place, be suitable for the work for which it is intended. Provision must be made for proper care of the machine. Furthermore, under scientific management, instructions must be furnished for the workmen, standardizing the work which he must do upon the machine.

(3) In regard to materials, the following things must be taken into consideration: First, the kind and quality of the material purchased, its price to the engineer or contractor, the cost of handling said material and its installation cost on the job.

(4) We must next consider the conditions and methods under which installation of work is conducted, whether by a consulting engineer, under direct supervision, or by a contractor at a fixed price. Under this heading we have several subdivisions to consider, in the following order:

(a) In the case of an installation being in the charge of either a contracting or a consulting engineer, a preliminary plan should be made, subject to the approval and acceptance of the owner and his architect. Certain alterations are reasonably certain to be necessary in this plan, subject to the owner's correction. Then, in the case of a heating contractor bidding on his own specifications, a definite description should be made of all the work intended, and upon the drawings should be

clearly indicated the method of installing the work. Having in hand clearly defined plans and specifications covering the installation of the work, certain elements of functional discipline should be made plain to his employees, based absolutely upon the "square deal."

The next problem for the contractor is that of traffic; the moving of the material, which must be installed in connection with the heating contract. In this connection, I may state that it has been our experience in the last eight years that it is advisable to cut the pipe to dimension in the shop, and under no circumstances, is it necessary to cut pipe over 2 in. in size on the job. In this connection, the thought enters of standardizing the functions of a competent mechanic for steam fitting in the shop. Provided the architect's drawings are reasonably correct, there is no reason why all the large piping for either a steam or hot-water job should not be cut and threaded ready for installation, in the shop. It would therefore seem that the largest opportunity for an increase in personal efficiency of the worker is in the shop of the steam fitter, with competent instructions, and accurate measurements taken off the architect's plans and checked up on the job. In connection with the instruction of the mechanic or steam fitter, certain conditions necessary to the satisfactory operation of an efficiency plan are necessary. Adequate lighting must be provided in the shop, a sufficient supply of fresh air at a proper temperature is also necessary, and lastly but not the least important, an adequate reward must be given the worker for his increased *efficiency*.

Now, as to efficiency and a wage plan; it is absolutely *essential* that a standard be established in each shop and for each field job; that is to say, *work on the contract where* it is to be installed. This can be only made after careful "time studies" during a period of three to four months, have been made, and a fair analysis of the results have been tabulated.

As to heating contractors, our experience has been that they really know little or nothing as to the actual cost to them of contract work. They seem to ignore the following facts: that four principal constituents must be considered in any cost analysis of contract work. First, the material used; second, labor used; third, the equipment used; fourth, indirect expense. This last includes the expense in the office, shop, on the job and

"overhead" expense, the last item of which is ordinarily ignored in making up an estimate to bid on contract work.

In conclusion, we would suggest that the members of this Society give some thought to the application of the principles of scientific management to the heating trade. While the experience of our office does not include efficiency service for contractors in the heating business, we believe that there is a possibility of an increase in efficiency for the labor element in the heating industry of 30 per cent to 50 per cent, provided that the principles of efficiency engineering are observed.

It may not be amiss to say that from observations made in the past eight years, we have found that the waste effort in steam-fitting labor, owing to the lack of an advance plan, has been 50 per cent to 60 per cent, and that under normal conditions, even with union labor, the efficiency of workmen may be easily increased.

My suggestion to the members of the Society is to beg, buy or borrow the works of the eminent authorities first mentioned in this monograph and give them some thought, and it is my belief that with a body of men such as is here assembled, in the next twelve months, much may be done to increase efficiency, in both shop and office, of the heating contractor or engineer.

Possibly the members present would be interested in knowing how to make a time study of pipe fitting labor. The only apparatus needed by the observer is a stop watch, some ordinary cross hatch paper, the kind with ten squares to the running inch (100 squares to the square inch), a light drawing board, a small one that can be conveniently held in the crook of the left arm, about 18x24 in., some thumb tacks to fasten paper to the board and a soft lead pencil. The stop watch should be of the "decimal" type, the minute or outer circle of graduations being divided into hundredths instead of sixty parts as in the ordinary watch. A small dial registers minutes and the watch is arranged to stop and start with the thumb of the left hand. The watch is attached to the upper right hand corner of the board by spring clips or an arrangement like a wrist watch holder.

Now suppose we are making a time study of a fitter and helper, measuring, cutting, threading and fitting a piece of 1½-in. pipe for a riser connection on a job. Take the horizontal ordinate for your time in minutes and tenths, and place the

symbols for operations, waits, etc., the letters shown at the left of your vertical ordinate. (See Fig. 1.) The symbols may be interpreted as follows: M is for measuring at the point where fitting is to be made, and in this time include walking to the point and back to the work bench; M_2 is time for measuring length off on the piece to be cut, including time to walk to place where pipe is piled, sort it and bring piece and place it in vise; CT is time for cutting the pipe, preparing stock and dies and actual time threading the pipe; PF is the time of removing pipe from vise, taking it to the place it is to be connected and

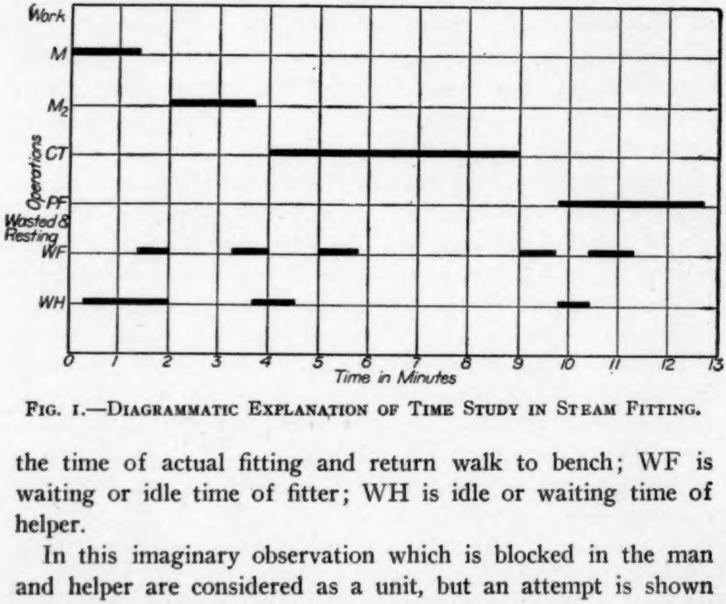


FIG. 1.—DIAGRAMMATIC EXPLANATION OF TIME STUDY IN STEAM FITTING.

the time of actual fitting and return walk to bench; WF is waiting or idle time of fitter; WH is idle or waiting time of helper.

In this imaginary observation which is blocked in the man and helper are considered as a unit, but an attempt is shown at recording idle or waiting time. In addition to a study of the two as a unit separate studies should be made so as to find out exactly the preventable waste time of each. Of course a proper allowance of rest time should be allowed, say 10 per cent, but I believe you will find the idle time to run very much more than this with the average fitter.

The items or operations we have taken for this rough study are capable of subdivision, and when it comes to the standardizing of the "one best way" of doing things they should be taken separately, split up into motion studies for the elimina-

tion of every useless motion and loss of time through lack of system in work planning. By application of efficiency principles 30 per cent to 50 per cent more work can be done by the average fitter and a fair part of the increase be a bonus.

DISCUSSION.

Mr. Wm. F. Devendorf (by letter): On every estimate which the contractor figures there is always one item over which he puzzles his brain long and earnestly, and that is the labor item. He knows what his boilers will cost, what he must pay for his pump, his pipe, his valves, etc., but as to just what his labor will cost he cannot tell except from past experience, and his knowledge of his men and the installation in question. Even after he has gone over the labor item and arrived at a figure his estimate may be found to be much too small, simply because his men may not have been properly supervised or because they may have been inefficient, or because they soldiered.

It has seemed to me that the proper solution lies along the lines of so interesting the men themselves in their work and the concern which employs them that they will give to their work their maximum skill and effort to eliminate the indifference that so often marks the usual fitter. I am glad to note that several efforts have been made along this line by the larger business enterprises, but the particular problem at hand is with the medium-sized contractor. Mr. James H. Collins, in the *Saturday Evening Post* of December 30, discusses this matter under the title of "The Spirit of the Company," and Mr. Chas. S. Kellum has an admirable continued article along the same line in "Radiation," the monthly paper issued by the United States Radiator Corporation.

The profit on an installation is largely determined by the men who actually do the work, the problem is, how to make them see that this is so, and when they do see it, what means or inducements should be necessary to induce them to give the best of their skill and energies to the particular work at hand.

Contractors will no doubt at once admit the great importance of this feature of their business and I believe that a discussion of the matter would bring out information that would be exceedingly valuable.

Mr. Barron: I am a strong believer in efficiency engineering and in Mr. Hill's work; and I think the statement that our friend made covers the whole subject. He says he has not had any practice in installation, that is, with heating contracts. But I have seen heating contractors who have employed efficiency engineering so that they could make their labor better; but my judgment is it never will. There is a natural economic law that settles those things and that has fixed the efficiency of the steam fitter, whether it is the open shop of the country or whether it is the closed shops of the cities like New York and Chicago. The men work at the maximum efficiency on an average. There are exceptional jobs in almost every shop, but, on the whole, the installations are at maximum for the time being. This is a very difficult, complex problem, and the kind of work that yields results to the efficiency engineer is different from steam fitting. On all ordinary work, men are working at their maximum efficiency, just as you now at that desk have been working at your maximum efficiency, and the rest of us here are working at our maximum efficiency. It is all right on the preliminary planning of construction and staff work generally, but on the installation there is no room for efficiency engineering. In my opinion the law of supply and demand insures that only the most efficient shop exists. It is a desperate struggle and the incompetent workmen get out of the business and the other men stay in the labor union or stay in the open shop.

The President: There is one thing certain, that all of us will at least try to improve our own efficiency, but a good deal of the stimulus that comes to us is in the shape of dollars. It is surprising how much you can get out of men if they are going to make a little out of it; and perhaps part of the application of the discussion as to efficiency methods and the work done by men is accompanied generally, and properly so, by some inducement, in the form of pay for the work that they have accomplished. If that includes a fair proportion of the increased results of their labors the men are contented and the owner has gained something. But I think if you are simply going to apply efficiency methods to the mere acquisition of more results, making more labor out of men for the same money you are paying them now, you are likely to find the result disappointing, as our good friend, Mr. Barron, seems to have found.

Mr. Hill: I want to correct an apparently wrong impression that you have. Now under any plan of scientific management, no matter whose it is, Taylor's, Gantt's or Emerson's or anybody else's, a reward is paid for increased efficiency of the worker: a definite premium for extra effort. For instance, take a steam fitter, whose pay in New York is, say $5.50 a day, and a helper, $3.00. Now, whether this is a just amount for what the average output of actual work done, the heating contractors of New York should know, should determine scientifically. Now, under scientific management (and though I didn't say this in my paper—I want to now), the application of efficiency principles, while possible for almost any trade, the actual installation of this plan of management must be expertly done and done slowly. There has been a strike in the government shipbuilding and repair plant at Norfolk, due to the fact that the engineer in charge attempted to install scientific management in too short a time. You can't do it, Gentlemen! It must be a very gradual process, the conversion of man after man, individually or in very small groups, whether your organization includes ten men or hundreds of them. To apply efficiency methods each man is first to be convinced in his own mind of the fairness of the plan and see that it means the "square deal," more pay for more work, an adequate and immediate reward.

Now, for example, I happen to have had a shipbuilding client. Their machinists get from $3.50 to $4.00 a day. We found it worth while to pay them on a plan of premiums. Usually this premium amounted to from 30 to 40 per cent. of the actual value of his increased efficiency. That is to say, a man working at a day rate of, say $4.00, if he actually turns out (according to the standard of performance which has been scientifically determined and set for the shop's various production units) $5.00 worth of work he should receive $0.30 extra pay for the day. The remaining $0.70 goes to the management to reimburse them for the expense of the new plan of management installation and is in a way a premium to the management for making it possible for the man to make more money. With the establishment of a standard the relative merits of the workers can be accurately measured and frankly, as to incompetents, scientific management tends to eliminate them.

The labor unions have generally opposed the installation of

efficiency methods, and the individual's performance as a basis of wages, for though the unions claim to insure the employers' getting competent workmen, as a matter of fact, in actual practice, we all know, they are often protecting incompetents. If you are working closed shop in New York and pay $5.50 a day for fitters, while you may get some men who are worth that or more, you probably get many who are not. If efficiency is your basis of wage payment you weed out the incompetents and the good men are able to make more money and yet the actual output of useful work per dollar payroll is greatly increased. The men realize that it pays to get busy; that more efficient service by their own effort means that they can consistently earn more money and that the reward is in their envelopes every pay day.

CCLXXXIII.

AUXILIARIES FOR PRESSURE SYSTEMS OF HOT WATER HEATING.

BY J. J. WILSON.

Because of the increasing demand and use of hot water heating auxiliaries, such as generators, accelerators, impulsers, heat retainers, etc., in hot water heating systems, especially those used for residence heating, the author is led to believe a description of the methods used to install some of these specialties may be of interest. In 1896 he was engaged to design a hot water heating system for a small hotel, having about 41 radiators. After going over the building plans, he decided to have the heating contractor put in a closed or pressure system of hot water heating.

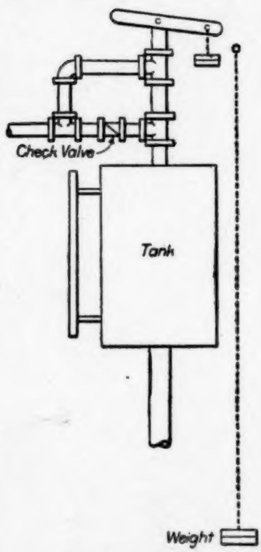


FIG. 2. FIG. 1.

An overhead system was designed with the mains on the fourth story ceiling, and the expansion tank was placed in an accessible position, between the ceiling and the roof. The author used a lever safety valve on the tank, a chain from the lever down into the room under the tank, upon which chain weights could be placed, to increase the water temperature in the system, when operating. Fig. 1 shows auxiliaries attached to tank.

In 1903 the author designed a hot water heating system for a fire-engine house. The mains were located in the cellar and tank

was placed above the highest radiators. Fig. 2 explains the construction at the tank. In both of these cases, good results were secured, as to quick circulation and moderate use of fuel. It is believed that both of these plants are still in use and giving satisfaction.

In 1906 a number of calls were received to design systems of this character, and after trying several specialties used in closed or pressure systems, the author settled on the Phelps heat retainer, shown in Fig. 3. He has designed about sixty systems using this specialty, and in every instance has secured good results in quick circulation; and where proper attention was given to operating the boiler fire, economical results were obtained in the use of fuel.

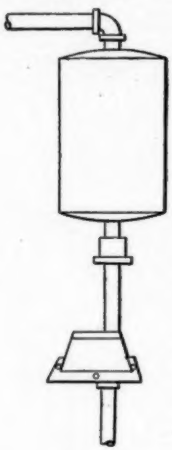


FIG. 3.

In 1909 the author was engaged to design a hot water heating system for a heating contractor who had considerable experience with closed systems of hot-water heating. The heating plant was for a residence in the Blue Ridge Mountains, in a location much exposed to high winds and low temperatures. The heating contractor had invented a novel method of installing his expansion tank in the cellar alongside of the boiler and also a system of damper and draft control in conjunction with the other specialties. This system was installed and proved a success. Several plants of this kind were installed in 1910, the inventor making an improvement in the different attachments used. Finally he obtained a patent this summer on the invention, and now has applied for a patent on his draft control.

Fig. 4 shows the tank and complete construction. The tank of 20 gal. is located in the cellar at any desired location, but preferably alongside of boiler. The pipe connecting the bottom of tank with the boiler return has a valve to cut off such connection when desired. The top of the tank has a relief valve on it and an attachment for operating a lever arm that closes and opens draft door on boiler and the check draft damper on the smoke pipe. On the side of the tank, attached to tank draw off,

there is connected a small air pump, similar to those used for obtaining a pressure in gasoline fire pots, and alongside of it on same run of pipe is connected a pressure gauge.

The operation of the system is as follows: The valve on the line between the boiler and the tank is closed and the system filled with water, as it is usually done, then 2 buckets or about 10 gal. of water are drawn from the system. Air is pumped into the tank until, for a two-story residence, the gauge registers about 5 lb.; for a three-story residence, about 8 lb., and so on, the object being to have enough pressure to balance the height of water in system, so that the top radiators are kept full of water. Then the valve between the tank and boiler is opened and the gauge will register about zero. Fire is then started, and system is operated by means of damper arm at the tank.

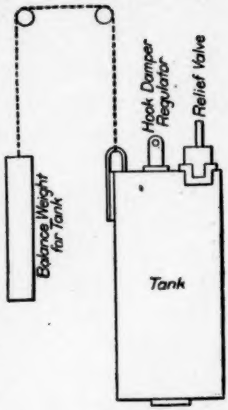


Fig. 5.

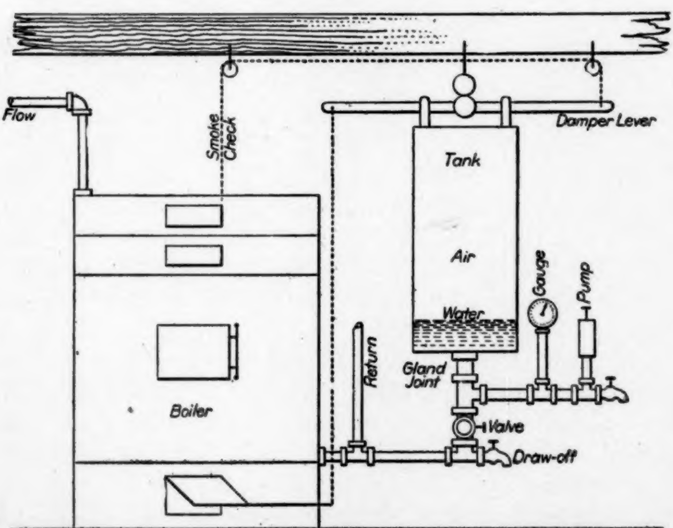


Fig. 4.—Combined Expansion Tank and Draft Control.

Draft can be set to close off at any pressure desired. We have used from 4 to 10 lb. at the gauge.

We find that the system is extremely sensitive to the action of the fire; circulation is very rapid and equable. The most distant radiator from the boiler heats almost simultaneously with the one nearest boiler. As soon as the pressure in the system exceeds the amount desired, water from the system enters the expansion tank and thus increases its weight, causing it to drop through a gland joint in the connection between it and the boiler. In dropping, it tips the damper lever arm, causing the draft door to close and the check draft in the smoke pipe to open. As soon as this excess pressure subsides, as it will do, caused by checking the draft, the tank, which is balanced by a counterweight, shown in Fig. 5, resumes its former position, and the draft door of boiler is opened and the smoke pipe check damper closed.

The distance the tank drops from the expansion of water into it is only ½ in. The fulcrum and lever arm multiplies the distance of the tank drop sufficiently to operate the draft door and the smoke-pipe check. The use of the air pump in connection is a valuable feature, as it enables the operator to have a resilient cushion of air to balance the static height of the water in the system. The relief valve at the top of the tank is designed to make it impossible for the valve seat to stick. So far the inventor has never met the condition of the water escaping from this relief valve. The amount of radiation used to heat rooms connected to this system has been decreased from 10 to 15 per cent. of the amount used for an open system of hot-water heating.

The sizes of the flow and return mains are also reduced, their area being not less than the total sum of the area of all radiator connections, which are usually as given in the table:

SIZE OF HOT WATER RADIATOR PIPE CONNECTIONS

First Floor:	
Up to 50 sq. ft. Radiation	¾ in. pipe
Up to 100 sq. ft. Radiation	1 in. pipe
Second Floor:	
Up to 50 sq. ft. Radiation	½ in. pipe
Up to 100 sq. ft. Radiation	¾ in. pipe
Third Floor:	
Up to 60 sq. ft. Radiation	½ in. pipe
Up to 120 sq. ft. Radiation	¾ in. pipe

All branch connections are taken from the side of flow and return mains, using two 45 deg. ells to get the proper elevation.

The inventor in experimenting as to the effects produced by high pressure, running at one time as high as 30 lb., indicated on the tank gauge, notes there does not seem to be any leakage in system, and ascribes this condition to the resilient cushion of air that the water presses against. The locating of the tank in the cellar, together with the other mentioned auxiliaries, in connection with a hot-water heating system, seem to the author to be far in advance of anything heretofore designed for such a purpose. At this writing more definite engineering data, such as outside temperatures, temperatures of rooms, amount of radiation, amount of fuel burned per square foot of grate surface, velocity of water through mains and other desirable data are not available, as the plants are in a distant State, but it is hoped in the near future to be able to supply the information. The system is known as Walter's areo-balance system of hot-water heating, and was invented by Felix Walter, of Highfield, Md., but as yet has not been introduced outside of his personal contracting.

DISCUSSION.

President Bolton: This appears to be a description of a fool-proof apparatus such that I should suppose even an ordinary house owner may be able to operate, if he has nothing more to do than pull that pump up and down. The trouble with most of our automatic apparatus is, as we have frequently found on discussion here, that these appliances are of too complex a character for the ordinary householder to keep in repair and maintain in proper condition. We shall be glad to hear from any of our members on the subject.

Mr. Donnelly: I am surprised at the statement that this is simple and fool-proof. I think it is very complicated in details.

The President: I understand that Mr. Donnelly's recommendation or suggestion that this has a large application must be in the interest of the repair trade then. I think, however, it must be taken for granted that Mr. Donnelly's criticism is good and that the placing a valve in that position involves liability to danger, unless there be some other connection that will relieve the boiler automatically. It is surprising how persistently people who have to handle domestic apparatus will insist upon doing just the wrong thing in an appliance of this kind.

I recently investigated the operation of a Honeywell system in a small dwelling, and I think that everything had been done that could be done to put the system out of business. It must be very discouraging sometimes to be an inventor of hot water heating systems.

CCLXXXIV.

TESTS OF VACUUM CLEANING TOOLS AND EXHAUSTERS.

BY M. S. COOLEY.

The tests described below were made by the author three years ago and were primarily to determine: 1.—The feasibility of using a carpet cleaning test to determine the merits of a vacuum

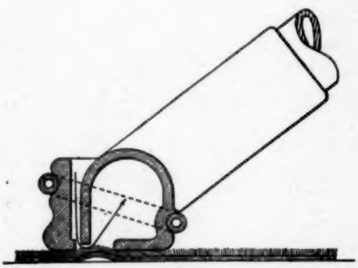


FIG. 1.—TYPE A CARPET RENOVATOR.

FIG. 2.—TYPE B CARPET RENOVATOR.

cleaning system. 2.—To fix the requirements to be incorporated in a specification, where acceptance of the system was dependent on a satisfactory cleaning test. 3.—To determine what requirements, rather than a cleaning test, would be necessary to obtain a first-class cleaning system.

In making carpet cleaning tests, three types of carpet renovators were used, which the author has referred to as types A, B and C, in the order in which tests were made. Sections of these renovators are shown in the illustrations, and they may be briefly described as follows:

Type A: This renovator has a cleaning slot 5-16 in. wide and 12 in. long in communication with a second slot, open to atmosphere through an opening under the dividing partition which stands 1-32 in. above the working face of the tool.

Type B: This renovator has a cleaning slot ⅛ in. wide and

12 in. long, with no openings for admission of air other than the cleaning slot.

Type C: This renovator has a cleaning slot ¾ in. wide and 10 in. long, with no openings for admission of air other than the cleaning slot.

In the first test made at Philadelphia a glue sized brussels carpet, which had been in use for many years, was divided into three equal parts and each one cleaned for 6 min., using a type A renovator. The vacuum at the tool handle varied for each carpet. Indicator cards were taken from the vacuum pump during each test and the number of cubic feet of air calculated therefrom. At the conclusion of these tests each carpet was cleaned until no change in weight occurred after 2 min. cleaning. They were then considered clean. Carpets were weighed to ¼ oz. in all cases. The result of the test is given in Table I.

TABLE I—TEST WITH RENOVATING TOOL A, SHOWING DIRT REMOVAL, PER CENT. OF TOTAL

Time, minutes	Vacuum at handle, in.		
	1	2½	4
1	37	39	47
2	52	50	63
3	59	66	71
4	61	72	83
5	66	75	87
6	67	82	90
Air, cubic feet per minute	30	43	50

Each of the carpets measured approximately 7 sq. yd. and contained when received approximately 12 oz. of dirt.

An attempt was then made to obtain some substance with which carpets could be artificially soiled, which would be as difficult in removal as dirt ground in by usage. The results were far from successful and no substance was found that was nearly equal to a soiled carpet. The following were tried on the same carpets used in the first test:

Wheat flour was very easily and completely removed, as much as 3 lb. being completely removed in 3 min. with 3-in. vacuum at handle.

Portland cement: 95 per cent. was removed in 2 min. with 1 in. vacuum at the handle.

Molders' sand: 100 per cent. was removed in 3 min. with 2½ in. at the tool handle.

Carpet was covered with wet mud and then dried; 100 per

cent. was removed in 3 min. with 2½-in. vacuum at the tool handle.

Finally, dry, sharp builders' sand, screened through a 50-mesh screen, was used and found to be most satisfactory, and tests were run as summarized in Table II.

TABLE II—TEST OF REMOVAL OF BUILDERS' SAND WITH TOOL A, PER CENT. OF TOTAL

Time, minutes	Vacuum at handle, in.		
	1	2½	4
1	45	61	50
2	60.5	75	75
3	73.5	84	77
4	76.3	91	88
5	..	94.5	97
6	..	..	100
Air, cubic feet per minute	30	43	50

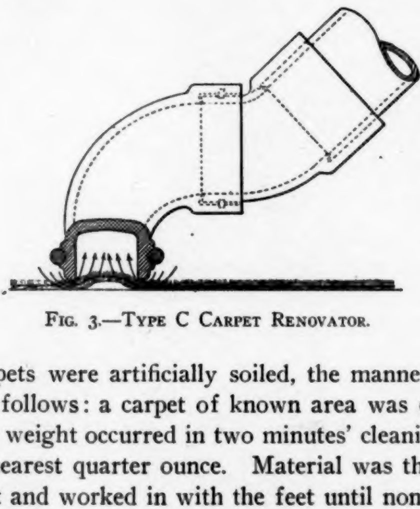


FIG. 3.—TYPE C CARPET RENOVATOR.

When carpets were artificially soiled, the manner of making tests was as follows: a carpet of known area was cleaned until no change in weight occurred in two minutes' cleaning, and then weighed to nearest quarter ounce. Material was then sprinkled on the carpet and worked in with the feet until none of it could be seen on the surface of the carpet. The carpet was then weighed again, fastened down, and cleaned for a predetermined interval of time, and the carpet again weighed. This procedure was repeated until all dirt was removed.

It was found that in rolling carpet, to weigh it after filling with dirt, some of the material was shaken loose. After a few trials, weighing the carpet before filling, weighing the material before placing, and weighing the carpet after filling, it was found that no measurable loss of material occurred in working it in. In subsequent tests, the carpet was weighed clean and

fastened down and the material weighed and worked in with a considerable saving of time.

It being considered advisable to make cleaning tests with other types of renovators, a renovator of type B, the only other type of renovator available in Philadelphia, was obtained, and as no more dirty carpets were available, tests with dry sharp sand were run on the same carpets as before, using type B renovator, with results given in Table III.

TABLE III—TEST OF REMOVAL OF BUILDERS' SAND FROM CARPET, WITH TOOL B, PER CENT. OF TOTAL

Time, minutes	Vacuum at tool handle, in.	
	2	4½
1	48	54
2	70	87
3	91	100
4	100	
Air, cubic feet per minute	24.5	39.5

Shortly after making these tests the author was afforded the opportunity to test a renovator of type C. However, the exhauster available would not produce a vacuum of more than 6 in. of mercury and this vacuum could not be readily controlled. Therefore all tests were made with 3½ in. of vacuum at the tool handle. Tests were run on a dirty carpet containing 4 sq. yd., and when received approximately 6 oz. of dust and also on carpets filled with sand with the results given in Table IV.

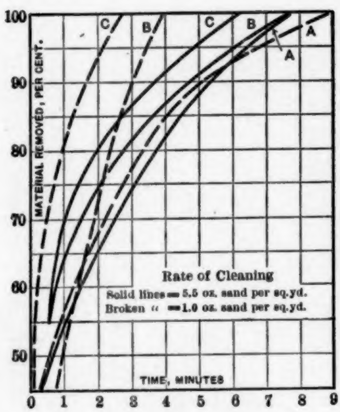
TABLE IV—TESTED WITH RENOVATOR OF TYPE C.

Time, minutes	Dirt removed, per cent. of total	Sand removed, per cent. of total
1	40	68
2	60	82
3	90	100
Air, cubic feet per minute	66	66

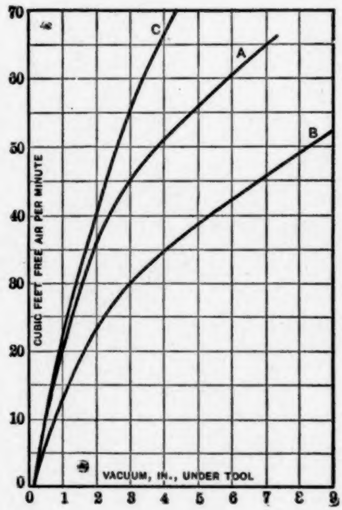
Taking results from all these tests with a vacuum at handle of 3½ to 4½ in., the number of cubic feet of air required to remove 1 oz. of sand with the three types of cleansers is: type A, 50 cu. ft.; type B, 17 cu. ft.; type C, 22 cu. ft.

This is with carpets containing approximately 1 oz. of sand per square yard of carpet, which was the maximum that could be rubbed into the carpet used at Philadelphia, and from tests on dirty carpets this is approximately 70 per cent. of the amount of dirt we would find in a very dirty carpet.

Having at hand the thesis of Mr. Stewart R. Miller, of the Massachusetts Institute of Technology, in which he reported tests on type A and B renovators, removing 5½ oz. of dust per yard of carpet, a long-fibred carpet was obtained and tested, using type C renovator with the carpet filled at the rate of 5½ oz. of dust per yard. Making deductions from tests made by the author, he approximated the number of cubic feet of air exhausted in the Massachusetts tests and ascertained the number



FIGS. 4 AND 5.—TESTS OF RATE OF CLEANING.



AIR REQUIRED BY CARPET RENOVATORS.

of cubic feet of air per ounce of sand removed to be as follows: type A, 17.5 cu. ft.; type B, 10.9 cu. ft.; type C, 12.5 cu. ft.

The results are shown graphically in Figs. 4 and 5. Fig. 4 shows the rate of cleaning with the three types of renovators and Fig. 5 shows the number of cubic feet of free air per minute used during the tests.

In order to determine what effect the degree of vacuum at the tool handle had on the effort necessary to move the renovators over the floor, the various types of renovators were operated over various surfaces and were pulled along, using a spring balance, the pull registered being noted with the results enumerated in Table V.

An analysis of tests shows that in order to clean a carpet ef-

fectively, we must have some degree of vacuum under the tool itself. Merely a current of air is not all that is required. For example, note that with type A renovator with 30 cu. ft. of air passing and 1 in. of vacuum under the renovator but 76 per cent. of the sand was removed in 4 minutes. With type B renovator, with 24.5 cu. ft. of air passing and 2 in. of vacuum under the tool, 100 per cent. of the sand was removed in 4 min. On dirty carpets the result is even more marked. Apparently when working on a dirty carpet, it is the vacuum that loosens the dust from the carpet, the air acting as the conveying medium for removing the dirt loosened by the vacuum.

For rapid, thorough and effective cleaning of carpets and other fabrics of equal weight and thickness the author considers that a vacuum of at least 3½ in. at the tool handle is necessary. It is also evident that a vacuum very much higher than 4 in. or

TABLE V—TESTS OF EFFORT REQUIRED TO MOVE VACUUM CLEANING TOOLS

Type	Surface	Vacuum, in.	Pull, lb.	Air, cu. ft.
A	Velvet carpet glue back	6½	17	45
A	Velvet carpet no glue back	1	12	56
A	Brussels carpet glue back	6½	17	45
A	Linoleum	1	10	56
B	Velvet carpet glue back	8½	18	35
B	Velvet carpet no glue back	3½	15	50
B	Brussels carpet glue back	8	20	39
B	Linoleum	13	23	20
C	Brussels glue back	3½	11	66
C	Axminster	3½	13	66
C	Linoleum	4½	13	60

5 in. will cause the tool to stick and be hard to operate, and will be likely to cause undue wear on the carpets.

It is also evident from the last column of Table V that the number of cu. ft. of free air passing through the same renovator varies with the character of the surface cleaned. This characteristic is more marked with the type A renovator and is accounted for by the effect of the inrush slot or vacuum breaker.

Comparing the efficiency of these renovators as dust removers, type B is more efficient than type C, and both are vastly more efficient than type A. This can be accounted for by the construction of type A renovator, which received the bulk of its air under the partition between the cleaning and the inrush slot, while both of the other types receive air under both sides of the cleaning slot as indicated by the arrows in Figs. 2 and 3. Therefore type A renovator cleans on one side only, while the other

types clean on both sides. Further, much of the air passing under the dividing partition of type A renovator passes directly to the outlet without penetrating the nap of the carpet.

In actual carpet cleaning, we have to pick up and remove, besides the dust, matches, cigar and cigarette stumps, bits of paper and other small litter, which are obviously too large to pass the narrow slot of type B renovator. Therefore, the ideal system would be one using type C renovator and arranged to maintain

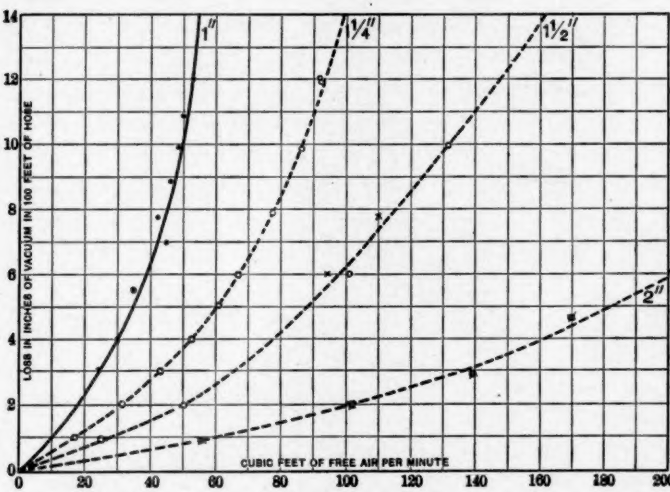


FIG. 6.—RESULTS OF TESTS OF FRICTION LOSS IN CLEANING HOSE.

a constant vacuum of 3½ in. to 4 in. at the handle irrespective of the quantity of air passing.

The control of the vacuum at the vacuum producer with varying quantities of air passing is a simple matter. However, there are other elements in a complete system between the renovator and the vacuum producer which affect the control of the vacuum at the renovator. These are the hose, pipe lines and dust separators.

Fig. 6 shows the results of actual tests of the friction loss in cleaning hose of 1, 1¼, 1½ and 2 in. diameter. The effect of friction in 1-in. hose is also shown in tests with the spring balance. In all tests of type A and B renovators 100 ft. of 1-in. hose was used and 15 in. of vacuum was maintained at the hose

cock. We see that with the vacuum at hose cock maintained at 15 in., the vacuum at the tool handle varied from 1 to 13 in., due to the variation in the quantity of air passing into the renovators when operated on various surfaces.

It is also noted that while the vacuum at the handle varied from 3½ to 13 in. with type B renovator, with type A renovator a variation of 1 to 6½ in. was obtained, operating over the same surfaces. This condition is due to the effect of the inrush slot which acts as a vacuum breaker when the renovator is operated on smooth surfaces or dense fabrics, and thus prevents the sticking of the renovator. This, however, is obtained only at a sacrifice in cleaning efficiency of the renovator as the leakage or by-pass effect of the inrush slot is always present. Better results can be obtained by using type B renovator, placing a spring-actuated vacuum breaker in the tool handle set to open at 5 or 6 in. of vacuum.

Much better results, however, can be obtained by using type B or C renovators in connection with 1½-in. hose. In this way the total variation in vacuum, when operating on various kinds of surface will not exceed 1 in. for type B renovator, nor 1½ in. for type C renovator, and without recourse to any type of vacuum breaker in the renovator or tool handle and with a consequent saving in the power expended.

Pipe lines add their friction effect to that of the hose lines, but in a far less marked degree, as they are seldom made less than 2 in. in diameter. With a system so designed that the maximum length of hose necessary will not exceed 75 ft., and with the 1½ in. diameter hose and ample sized pipe lines, the maximum loss in vacuum between the tool handle and the vacuum producer will not exceed 3 in. With this system and a vacuum producer maintaining a constant vacuum of 6 in. a good control of the vacuum at the handle will be had without the use of any vacuum breakers. In designing pipe lines, care must be exercised that the velocity in these lines never falls below 2,500 ft. per minute, or dust will be deposited in the pipe lines.

The tests show that with a carpet cleaning test as the only requirement, one may expect to get a system using type B renovators, 1-in. hose small pipe lines, a movement of air of approximately 25 cu. ft. per renovator, a vacuum at exhauster of about 10 in. and a small vacuum producer. While this system

will meet the carpet-cleaning test, it will not pick up ordinary litter, and when used for cleaning bare floors, relief work and the like will be ineffective, due to the small volume of air which is the essential quality for this character of work.

I consider that to obtain the best results in a cleaning system, the width of cleaning slot should be required to be not less than ½ in.; the length of the renovator not less than 12 in.; the

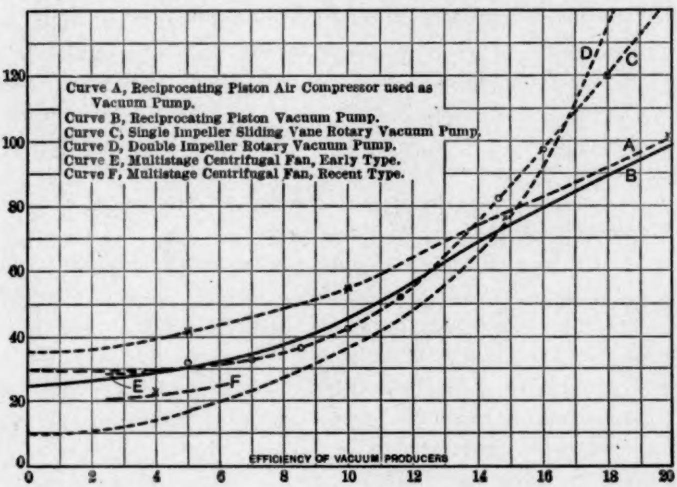


FIG. 7.—POWER CONSUMPTION OF SIX DIFFERENT TYPES OF VACUUM PRODUCERS; ORDINATES SHOW THE POWER CONSUMPTION OF MOTOR IN WATTS PER CUBIC FOOT OF FREE AIR EXHAUSTED PER MINUTE, ABSCISSÆ VACUUM IN INCHES OF MERCURY.

diameter of the hose 1½ in.; that the pipe lines should be not less than 2½ in. in diameter, except where lifts occur where 2 in. should be used; that the vacuum control be set to maintain 6 or 7 in. of vacuum at the machine.

The following test is suggested to give the best results: Fit a 1½-in. diameter pipe 3 ft. long into the end of the hose, with a diaphragm at the outer end and a vacuum gauge mercury column near the hose. Require a vacuum at mercury column of 3 in. with 65 cu. ft. of air passing into the tube, and as many hose lines and tubes in operation as the capacity in sweepers desired. This test will acquire approximately a ⅝ in. diameter opening in the diaphragms.

VACUUM PRODUCERS.

Fig. 7 shows curves of power consumption of six different types of vaccum producers based on tests made by the author. Curve A is from a reciprocating piston air compressor used as a vacuum pump. Curve B is from a reciprocating piston vacuum pump especially designed for vacuum cleaning and shows a higher economy than A. Curve C is from a single impeller sliding vane rotary vacuum pump and shows equal economy to B up to 12 in. of vacuum, above which its efficiency falls off. Curve D is from a double impeller rotary vacuum pump, water sealed, which shows much better economy than B below 14½ in. of vacuum. Curve E is from an early type of multistage centrifugal fan and shows an efficiency about equal to B and C. Curve F is from a recent type of multistage centrifugal fan and shows an efficiency better than any except D.

At 6 in. of vacuum these vacuum producers can be rated in the following order relative to efficiency: 1, D; 2, F; 3, B; 4, E; 5, C; 6, A. D will require a vacuum control in actual operation, which control should preferably be of variable speed type, while type F maintains a constant vacuum due to inherent properties of its construction, and where first cost is of vital consideration its use might be preferable to D. Both D and F are subject to considerable noise and vibration, unless the peripheral velocities of fans and impellors are limited. The author recommends a maximum velocity of tips of impellors of 1,100 ft. per minute in D and over 15,000 ft. per minute in F.

CCLXXXV.

HEATING A SWIMMING POOL.

BY C. TERAN.

A swimming pool is generally a luxury, not a necessity. For this reason not many are built, and a description of the system installed for Mr. Herbert Coppell at Tenafly, N. J., may prove of interest.

It is housed in a building of one story, and includes the pool room, two dressing rooms, boiler and coal rooms, all on the ground level. The pool is sunk below grade, is built of concrete, waterproofed and lined with English size enameled brick. It is 38 ft. long, 15½ ft. wide and 6 ft. mean depth below water level. The cubical contents are, therefore, 3,534 cu. ft.

The heating plant was designed to heat this volume of water in 10 hr., or at the rate of 353 cu. ft. an hour. Ten hours is a convenient length of time for heating the water, because the required apparatus is not specially large. If the apparatus was much smaller it would, of course, require a longer time to heat the water, and this time added to that necessary to empty and clean the pool would make the period of time which the pool would be out of commission too long. The time required to empty and clean this pool is 4 to 5 hr.

The installation includes two cast-iron sectional boilers, a Berryman service heater and a filter. The water is reduced to 30 lb. pressure on entering the building. It is then heated in the Berryman heater by steam generated in the boilers, and it is then filtered and discharged into the pool. For filling a main inlet is used; this enters the pool at the deep end near the bottom; there is also a nozzle above the waterline which is used to produce a spray over the pool.

On account of the proximity of the walls of the pool to the outside ground a loss of heat in the water was anticipated and provision made to replace the loss. Careful consideration was given to the various methods that could be used to accomplish

this purpose, and injecting water heated to a high temperature into the filled pool was decided upon. The reason for using a high temperature is that the water is not taken from the pool to be reheated, as this would necessitate a circulating pump, but fresh water is used, and by heating it to a high temperature a minimum quantity of water is required and less coal burned. Steam was not considered a good medium, because it imparts a peculiar odor to the water, due perhaps to the presence of oil in the boiler. The water is injected at four points on each side of the pool near the bottom, through nozzles passing through the brick lining and flush with it. This arrangement gives a good distribution, and is neat in appearance. It is found that during the winter months the water loses 2 to 3 deg. F. in 24 hr.

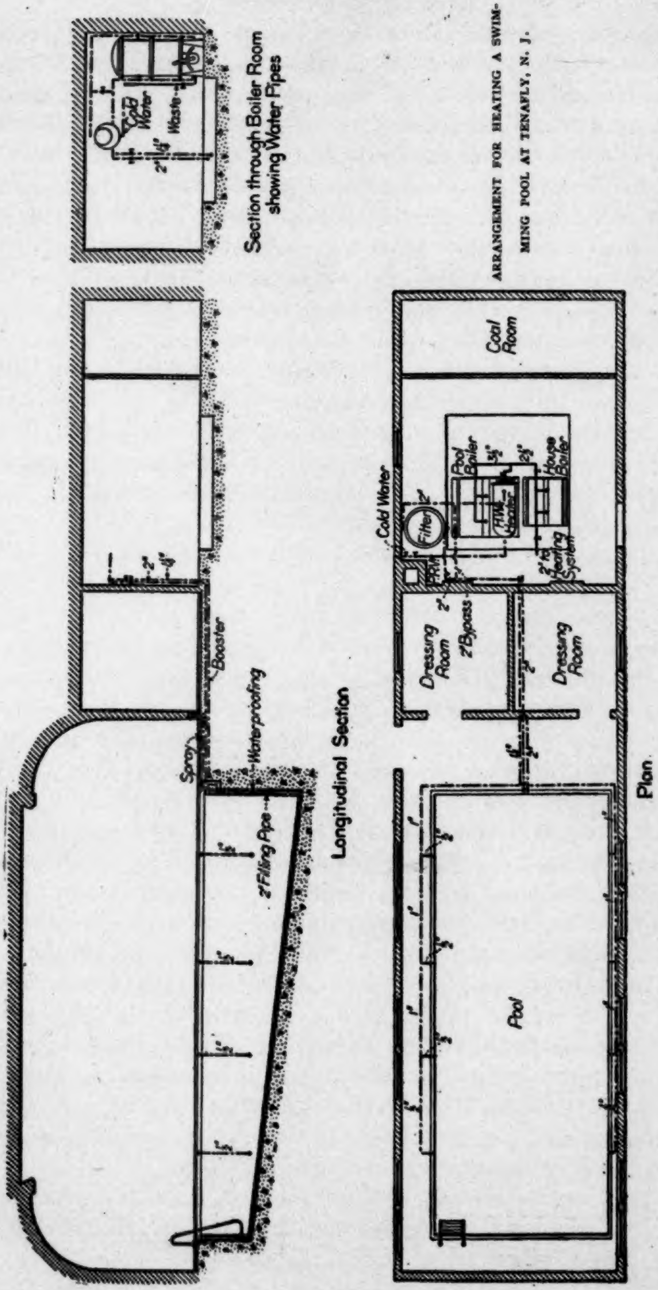
In filling the pool the water is heated to 75 deg. F., which, on account of heat losses in transit, etc., gives an ultimate temperature of 70 deg. F. The water injected to make up the heat loss is heated to 180 deg. F.

The large boiler is used to heat the water when the pool is being filled. This was computed as follows:

Cubical contents of pool	3534 cu. ft.
Cubic feet of water to be heated per hour,	353 cu. ft.
Pounds of water to be heated per hour,	353 x 62.4 = 22027
Rise of temperature of the water from 40 to 75 = 35 deg.	
Heat units transmitted to water per hour, 22062 x 35,	771,000 B.t.u.
Coal necessary to be burned per hour 771,000 ÷ 8000	96 lb.
Grate area 96 ÷ 8	12 sq. ft.

A boiler having a grate 40 in. wide by 48 in. long was installed. The other boiler shown is used to heat the building and to heat the water injected into the pool to make up the daily loss of heat; by this arrangement, the necessity of keeping a fire in the large boiler is avoided. As there was no sure method of predetermining the loss of heat of the water in the pool, in selecting this boiler liberal allowance was made for this purpose above what is required to heat the building. The amount of direct radiation in the building is 400 sq. ft., all behind screens; the boiler is rated at 1,000 sq. ft., and has a grate 21 x 27 in., or about 4 sq. ft.

The service heater was specified of proper size to heat 2,800 gal. of water per hour from 40 to 80 deg. F. with low pressure steam, and it was left to the manufacturers who furnished it to



ARRANGEMENT FOR HEATING A SWIMMING POOL AT TENAFLY, N. J.

design the proper size heater for this duty. The filter was specified in a similar manner. No automatic temperature control was installed, and none has been found necessary. An even temperature of the water is attained by maintaining a steady fire and regulating the flow of water by hand.

As a matter of precaution against a leaky pool the water pipes were installed so that they do not pass through the waterproofing of the wall of the pool below the waterline. This was accomplished by installing the pipes horizontally under the floor of the pool room and dropping branches to the proper depth in the pool between the waterproofing and the brick lining. All concealed water pipes are brass; other pipes are galvanized iron.

The pool, which may be considered an experiment, has been so satisfactory that Mr. Coppell has ordered built a much larger pool, 44 ft. long by 26 ft. wide, with the addition to his house and the equipment for the new pool has been designed on the same principle as the one described.

DISCUSSION.

President Bolton: Mr. Teran has given a description of a method of heating and running, specially designed for the purpose of a pool, which affords interesting information on the subject. Most of us who have had to deal with the same problem of heating have had to deal with it as an auxiliary to other appliances. I have used for the purpose of filling such pools a pipe provided with a series of nozzles, laid in a trench constructed at the lower end of the pool, this trench being provided with a removable cover, perforated. The trench is also utilized as a drain for the solid materials which are left on the bottom of the pool by being connected into a small sump chamber, from which it is easy to remove the sediment that gathers on the bottom of the bath. This sediment is mixed with fine hair from the human body and is rather difficult material to get rid of by mopping up. My method of connecting the piping has been to form a channel down one of the side walls on the extreme lower corner of the bath, extending down into the sump. In this is placed the suction pipe extending down into the sump, so that the very last drop of water can be drawn away from the interior of the bath. In the same channel the

hot and cold water supply pipe are extended and connected into the nozzle pipe, which is laid in the trench across the lower end of the bath. Thus, either hot or cold water, or both mixed, can be injected into the deepest part of the pool. No difficulty is found in introducing the hottest water that way, even while people have been in the bath, because it is distributed over a number of nozzles and it distributes itself before it strikes the person of the swimmer in the pool. I am sure other members must have data in connection with the subject.

Mr. Feldman: I do not see the objection to injecting steam.

The President: They use a boiler compound for over-heating. They do not use a boiler compound with a low pressure heating system.

Mr. Feldman: I am heating a fine swimming pool in that manner and never had any trouble. It is surely more economical, than heating the water in a heater. The second point, I do not see any reason why he filters the water he heats. I think it should be filtered before, so as to keep out the sediment from the heater.

He also speaks about the economy in heating water to a higher temperature by re-heating it. I disagree with it, as with high temperatures there is considerable evaporation. The greatest economy will be attained by delivering the water just a few degrees above that required.

Mr. Theodore Weinshank: The paper presented by Mr. Teran is a description of a method of heating water for a swimming pool and apparently was not designed by an engineer, but the apparatus and the application were left to the discretion of a manufacturer of certain specialties or of certain devices. The specific method described in the paper is not new and is somewhat crude, yet a benefit will be derived from the paper as a discussion of it may lead to suggestions for more modern and efficient methods.

While it may be true that there is no sure theoretical method of predetermination of loss of heat from the water in a swimming pool, still the conditions which tend to govern this loss are more or less a fixed basis of calculation, viz., the construction of the pool, the location of the pool in the building, the frequency with which the pool is in use and the average number of people using the pool every 24 hours. It has been our ex-

perience that the average loss of heat is from 2 deg. to 5 deg., and never more than 6 deg. in 24 hours.

The pool described in the paper can be considered a comparatively small one; as the average size of swimming pools is about 20 ft. by 60 ft., with an average depth of 6 ft. The cubic contents of the pool described is 3,534 cu. ft., and to fill and empty this pool requires 10 hours and 5 hours, respectively. This is too long a period for the average pool to be out of service. I have in mind particularly a Y. M. C. A. building and

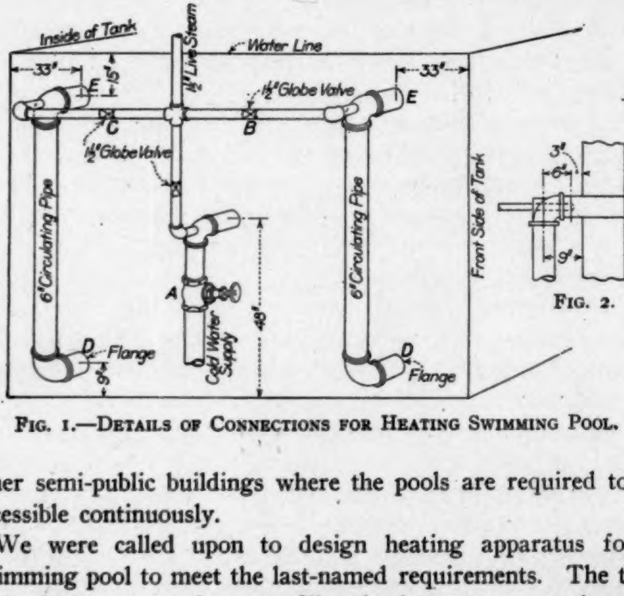


FIG. 2.

FIG. 1.—DETAILS OF CONNECTIONS FOR HEATING SWIMMING POOL.

other semi-public buildings where the pools are required to be accessible continuously.

We were called upon to design heating apparatus for a swimming pool to meet the last-named requirements. The time limit given us was 3 hours to fill and 2 hours to empty the pool, and the filling and emptying were to be done at night. The pool in question was 22 ft. by 60 ft., with an average water depth of 6 ft., containing about 450,000 lb. of water.

In designing the equipment we did not use any intermediate apparatus but heated the water by means of steam injection while the pool was being filled.

Referring to Fig. 1, the water was admitted to the pool at point A, about 4 ft. from the bottom, in the middle of the end wall at the deepest end, through a 4-in. supply from the city mains under pressure through a filter. The arrangement of

steam and water inlet is as shown in Fig. 2. The arrangement at point A, when used for filling the pool, was not with the intention of filling the pool with water of the desired temperature. The amount of steam used at point A was governed by the temperature of the incoming water and the rate at which it was desired to fill the pool.

After filling the pool, the valves at point A are closed and then valves B and C are opened and steam admitted at points E, E, 18 in. from the top of the water level. The arrangement of the connections at E, E are the same as at point A. The admission of steam at E, E causes a circulation of water through the entire length of the pool and causes the colder water to flow through inlets D, D upwards. By these means, we were able to bring up the temperature of the water to the desired point within a very short time.

With this design, the time limit required for heating the pool controls the boiler capacity. For example: to heat a pool 22 x 60 x 6 ft. from a temperature of 55 deg. F. to 75 deg. F., would require about 9,000,000 B. t. u. If this amount of heat is to be imparted to the water in 3 hours it would require about 90 h. p. This was the case in connection with the pool mentioned above.

A Member: How about noise?

Mr. Weinshank: We did have noise when pipes E, E were about 6 in. below the surface of the water. The velocity of the steam would push the water inward. We lowered the pipe about 18 in. and that overcame the difficulty.

We have installations of a similar character where cast-iron boilers under low pressure are used with good results for supplying the steam to the pool.

It is stated that steam is not considered a good medium as it will impart a peculiar odor to the water, due, perhaps, to the presence of oil in the boiler. Our experience, however, has been to the contrary.

Mr. Teran: In reply to Mr. Feldman's remarks about using steam to heat the water, the boilers installed in this work are cast-iron boilers. I did not want to feed these boilers continually with cold water; I was afraid they would break, and I prefer to reheat the water in the pool by injecting very hot water into it. If the boilers are made of wrought iron, of

course, you can use steam and have no fear of breaking them. As to why the water is first heated and then filtered, it is claimed by the filter manufacturers that this is the better way because some of the matter in solution in the water is precipitated in heating it, and it then can be removed by the filter. As to the high temperature of the water used to reheat the water in the pool, the water is introduced at the bottom, as I stated, and no steam rises to the surface. That would be more likely to happen in using steam than in using hot water at lower temperature.

Mr. E. S. Mobley: I had an experience some time ago in connection with the use of a boiler for heating a swimming pool. The water was heated by a hot-water circulating boiler set at one end of the pool. The water was circulated around to the other end of the pool and entered near the top, returning to the boiler from the end of the pool nearest the boiler. The top of the boiler was about 1 ft. below the water level in the pool. In about two and a half years the circulating pipe began to leak and I was called upon to repair it. They wanted me to put the pipe into the same end near which the heater is located, so as to save the tearing up of the cement pavement surrounding the pool, and then carry the pipe down to the bottom of the pool, with outlets at different places along the bottom. I refused to do it that way, knowing that it would give trouble, but another party undertook to do it that way, running the pipe into the same end of the pool near which the heater was located, dropping it down to the bottom of the pool and then running along the bottom to the center, grading up from the starting point and letting the water out in different jets. The next day they had to buy a new boiler. They did so and started up again. Now they have still another boiler to buy, and the trouble has not yet been remedied. My opinion is that they will still have trouble until they remove the pipe or put in an air valve at the high point.

CCLXXXVI.

DEFINITION OF THE UNIT OF HEAT.

BY REGINALD PELHAM BOLTON.

There does not appear to be any good reason for maintaining the use of the title "British Thermal Unit" as a description of the unit of heat, which forms the basis of modern thermal and thermo-dynamic computations. The title is unnecessarily clumsy. Furthermore, it is local, having the appearance of an assumption of priority on the part of one nationality, which is not suited to a matter of purely scientific nature, in which others are equally concerned.

The abbreviation of signs in some simple form is a desirable feature in connection with scientific computations and work. The clumsy "B. th. u.," which is still used by the Institution of Civil Engineers and other British institutions, cannot be justified on this ground. Reference to leading text-books indicates not only variation in the form of reference to this measurement, but in stating its value.

I append hereto extracts from books by several authorities, in which variations of value are shown, as well as some confusion in the duplication of the title applied to this simple element of computation.

It appears, from an examination of these and similar works dealing with subjects with which engineers are concerned, that the student is liable to be confused by a conflicting use of these abbreviations. In one recently published trade catalogue containing interesting and valuable material for reference, I observe the use of both abbreviations on the same page. These considerations indicate that there is much to be gained by the permanent adoption of the description of the basic unit of heat measurement, in its simplest form, the "Heat Unit," and its abbreviation by the letters *h. u.*, a method already adopted for practical convenience and in wide use among engineers and requiring only the sanction

of some recognized scientific body, such as this Society, in order to become a fixed part of the nomenclature of engineering science.

In order that this result may be effected in a regular and carefully considered manner, I propose that the standing Committee on Standards be requested to take this matter in hand and after due examination of authorities to make a recommendation for adoption by the Society.

VARIOUS REFERENCES IN STANDARD WORKS TO THE UNIT OF HEAT, SHOWING DIVERGENCIES OF DESCRIPTION AND NOMENCLATURE

HEATING AND VENTILATING BUILDINGS.
By Prof. R. C. Carpenter:

"In English-speaking countries the heat-unit is that required to raise one pound of water from a temperature of 62 to 63 degrees, and this quantity is termed a British thermal unit; this will be referred to in this work, by its initial letters, B. T. U., or simply as a heat-unit."

HEAT.
By Thomas Box:

"Unit of Heat.—It is necessary to have a standard for measuring the amount of heat absorbed or evolved during any operation; in this country the standard 'unit' is the amount of heat required to raise the temperature of a pound of water at 32 degrees, one degree Fahrenheit."

HEATING AND VENTILATION.
By Prof. James D. Hoffman:

"Measurement of Heat: In the measurement of heat, the most commonly accepted unit in practical engineering work is the British thermal unit, commonly abbreviated B. t. u., which may be defined as that amount of heat which will raise the temperature of one pound of pure water one degree Fahrenheit, at or near the temperature of maximum density, 39.1 deg. F."

ENGINEERS' POCKET-BOOK.
By William Kent:

"Unit of heat.—The British unit of heat, or British thermal unit (B. T. U.) is that quantity of heat which is required to raise the temperature of 1 lb. of pure water 1 deg. Fahr., at or near 39.1 deg. F., the temperature of maximum density of water."

ELEMENTS OF PHYSICS.
By G. A. Hoadley:

"The quantity of heat required to raise 1 lb. of water through one degree Fahrenheit, is called a British Thermal Unit (B. t. u.)."

THE STEAM ENGINE.
By Daniel K. Clark:

"Unit of heat.—The British unit of heat is that quantity of heat which is required to raise the temperature of one pound of pure water 1 degree Fahr. at or near 39.1 deg. F., the temperature of maximum density of water."

PHYSICS.
By Prof. G. F. Barker:

"A unit of heat is the amount of water required to raise the temperature of unit mass of water one degree between 0 and 4 deg. C."

ELEMENTS OF PHYSICS.
By Nichols and Franklin:

"The amount of heat, required to raise the temperature of one lb. of water one Fahrenheit degree, is much used by engineers as a unit of heat. It is called the British Thermal Unit and is equivalent to 778 ft.-lb."

DISCUSSION.

Prof. E. M. Shealy (by letter): The causes of the differences in the definitions of the British Thermal Unit as given by various authors may be understood when we consider the history of the several definitions. For many years after the study of the theory of heat was begun, the temperature of 32 deg. F. was looked upon as the standard temperature, and

all measurements of heat were based upon it, and it was but natural that English engineers should base their unit of heat upon the temperature of 32 deg. F., and also since water was a common and easily obtained substance, it was logical to define the unit of heat as the amount of heat which is required to raise the temperature of 1 lb. of water from 32 deg. to 33 deg. F. This unit was given the name of the British Thermal Unit to distinguish it from the French heat unit or calorie the amount of heat required to raise the temperature of one gram of water from 0 to 1 deg. on the Centigrade scale.

When it became known that the amount of heat required to change the temperature of water near the freezing point changed rather rapidly, and that water attained its maximum density at a temperature of 39.2 deg. F. or 4 deg. C., it seemed advisable at that time to base the heat unit on these temperatures, the definitions remaining otherwise unchanged.

The French unit of heat, the calorie, was found to be too small for many classes of measurements, hence a unit 1,000 times as large was used, known as the large calorie.

For many years the British thermal unit based on a temperature of 39 deg. to 40 deg. F. was used and this unit became deeply rooted in our engineering literature. About 15 or 20 years ago many American engineers began to realize that the British thermal unit based on 39 deg. to 40 deg. F. was unsatisfactory, as comparisons with this unit required the production of an artificial temperature, and that it would be desirable to have the heat unit based on a temperature of 62 deg. to 63 deg. F., which is about the ordinary room temperature of water used in making heat measurements. Steam tables were calculated on the basis of this new heat unit, notably those by C. H. Peabody.

Within the last three years, still other steam tables have been calculated on the basis of a heat unit defined as 1-180 of the amount of heat required to raise the temperature of one pound of water from 32 deg. to 212 deg. F. Marks and Davis's Steam Tables, 1909, are based on this average heat unit.

Wm. Kent, Mechanical Engineers' Pocket-book, Eighth Ed., 1910, gives both the definition of a British thermal unit based on a temperature of 62 deg. to 63 deg. and that based on 1/180 of the heat required to raise the temperature of one pound of

water from 32 deg. to 212 deg. F. The steam tables given in this handbook are taken from Marks and Davis's steam tables.

Prof. William Kent: Mr. Bolton quotes from an old edition of my Pocket-book. In the eighth edition, 1910, the old value of the B.t.u. was abandoned as obsolete, and the two values used by modern authorities, viz., the 62 deg. to 63 deg. unit, and the mean B.t.u. or 1/180 of the heat required to raise 1 unit of water from 0 deg. to 212 deg. F. were given. In the introduction to Marks and Davis's tables the reasons for adopting the mean unit are given, one of which is that it corresponds to the Bunsen or mean calorie in the metric system, the use of which calorie is increasing. The mean B.t.u. has been generally used in this country since the publication of Marks and Davis's tables in 1909.

CCLXXXVII.

REPORT OF THE COMMITTEE ON TESTS.

Records of Radiator Tests, made from December 9, 1911, to January 23, 1912.

CONTRIBUTED BY JAMES A. DONNELLY

In these tests the Committee has directed its attention to the general subject of the removal of air from the interior of steam radiators.

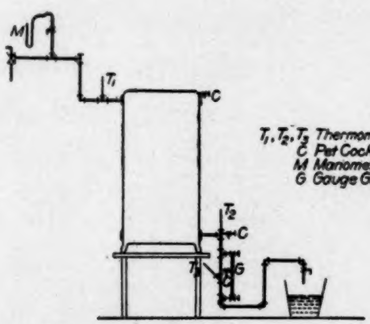


FIG. 1.—ARRANGEMENT FOR COMPLETE AIR REMOVAL.

This work was divided into three parts: first, to ascertain, if possible, the efficiency of a steam radiator with complete air removal; second, the comparative efficiency with varying air removal; third, the percentage of air removal which is obtained in ordinary practice.

The hot-water radiator was used in the test to find the efficiency of a radiator with complete air removal. It was connected as shown in Fig. 1, and the radiator was filled with water through the filling plug on the inlet. The water was then drawn sufficiently low so that steam could be blown across the top connection and out of the pet cock, thus presumably emptying the small pockets at the top of each section of air, and filling them with steam. The water was then drawn off at the bottom of the radiator and steam allowed to follow, so that the

radiator was filled with steam which was free from air. After the radiator was thoroughly heated and normal conditions established, records of the inlet temperature and pressure, room temperature, temperature at the return of the radiator and the temperature of the water of condensation were taken.

It was found that the maximum temperature of the water of condensation could not be maintained unless air and steam were continuously blown at the return of the radiator. When this vent was blown, the water of condensation would usually average about 204 deg., with a temperature at the steam inlet of 217 deg., and a room temperature of about 65 deg. The following table gives a record of a run with complete air removal:

RECORD OF TESTS MADE JANUARY 13, 1912

"Peerless" hot water radiator, 4 sections, 38 in. high, containing 20 sq. ft. of radiation with 2 sq. ft. added for pipe connections. The radiator was filled with water in order to obtain complete air removal; the pet cock on the return end was left cracked open and occasionally blown.

Time	Steam (deg.)	Return (deg.)	Water (deg.)	Room (deg.)	Condensation (lb.—oz.)	Pressure (in.—mercury)
10:00	216	215	201	60.5	....	3.3
10:10	216	215	197.5	61.5	1 2	3.1
10:20	216.5	216	197	62	1 2	3.7
10:30	220	219	200	62.5	1 3.5	5.5
10:40	220	219	200	63	1 2.75	5.5
10:50	219	218	198	63.5	1 1	5.
11:00	219	218	199	64.5	1 2.25	5.
11:10	217.5	217	200	65	1 1.75	4.
11:20	215	214.5	196.5	65	1 1.25	3.3
11:30	220	219	203	66	1 3.75	6.
11:40	220.5	220	207.5	66.5	1 2.25	5.9
11:50	219.5	219	209	66.5	1 2.25	5.2
12:00	218	217	208	67	1 2	4.2
12:10	218:5	218	208.5	67.5	1 2	4.9
12:20	219.5	219	209	67.5	1 2	5.3
12:30	218	217.5	206	68	1 1	4.7
12:40	219	218	207.5	68	1 2.25	4.7
12:50	219	218	207	68.5	1 1.25	4.9
1:00	220	219	·207	69	1 3	5.5
	19)4151	4136	3671.5	1242	3)20 6.25	19)89.7
Averages....	218.5	217.7	203.2	65.4	6 12.8	4.7

$$961.5+14.7=976.2\times 6.8=\frac{6640.16}{22}=\frac{301.82}{153}=1.072.$$

In ascertaining the comparative efficiency of radiators with varying air removal, the hot-water radiator was filled as before and then a certain percentage of the water was removed. This was presumed to leave a corresponding amount of air in the top of the radiator. When the filling plug and vents were closed, the steam was turned on and the radiator drained to the water-line in the gage-glass. The radiator was given sufficient time as before to reach its normal condition, by reason of the air and

iron heating up, when records of the pressure, temperature, etc., were kept for a run of three or four hours.

In this way the efficiency of radiators under these conditions was obtained and plotted as shown in Fig. 2. The temperature of the water of condensation seemed to serve as an in-

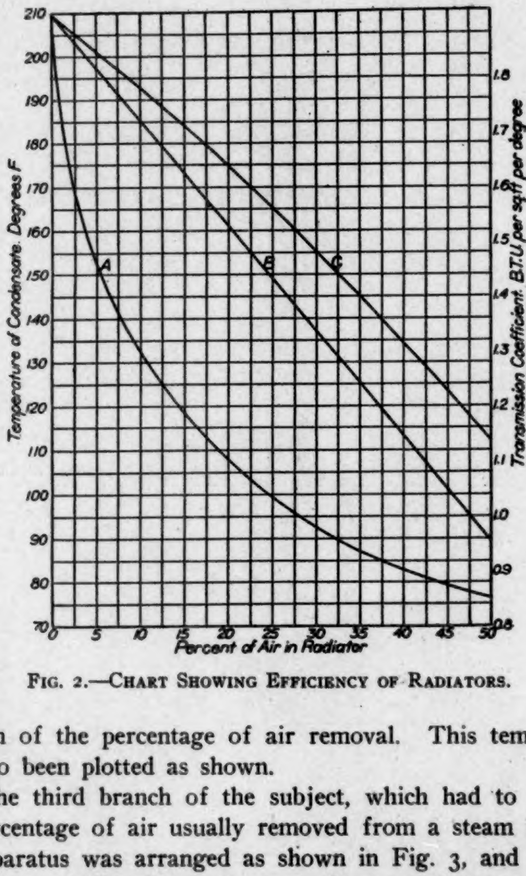


FIG. 2.—CHART SHOWING EFFICIENCY OF RADIATORS.

dication of the percentage of air removal. This temperature has also been plotted as shown.

In the third branch of the subject, which had to do with the percentage of air usually removed from a steam radiator, the apparatus was arranged as shown in Fig. 3, and the bottle "B" was filled with an amount of water which represented the capacity of the radiator and the piping from the inlet valve to the water line in the gage-glass. Steam was turned on the radiator and the air allowed to escape through the automatic air valve "A." The delivery of the water from the bottle was kept at or slightly above the water line in the bottle until the air

valve closed, when the delivery pipe was kept exactly at the water line so that the air in the bottle would be at atmospheric pressure.

It is by no means certain that this method of testing the air removal is very reliable, as the air is no doubt more or less heated by contact with the steam and is also increased in volume by having its humidity raised, probably to the point of saturation. The amount of air removed, also gases from kerosene oil, vary somewhat in accordance with the manner in which the last loop of the radiator heated. If the circulation was up the side opposite the air valve, the removal was somewhat higher

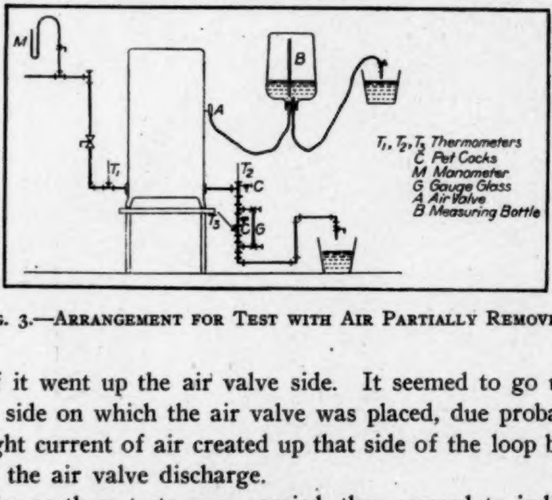


FIG. 3.—ARRANGEMENT FOR TEST WITH AIR PARTIALLY REMOVED.

than if it went up the air valve side. It seemed to go usually up the side on which the air valve was placed, due probably to the slight current of air created up that side of the loop by reason of the air valve discharge.

So far as these tests were carried, they seemed to indicate a removal of from 90 to 95 per cent. of air, though this is in all probability somewhat greater than the normal air removal.

Some observations were made upon two other methods of checking air removal; one by observing the temperature of the water of condensation from the radiator and comparing it with the temperature obtained from tests with known percentages of air removal, in the case of the hot-water radiator. The other by observing the weight of condensation and comparing that with the hot-water radiator tests. These observations, however, were not taken in sufficient number to arrive at any definite conclusion.

The automatic air valve was also placed at the point C, and the air removal tested. This seemed to be somewhat higher than in its usual location on the radiator. Air removal was also tried by a pet cock on the points A and C. These tests gave a higher temperature of water of condensation, and showed presumably a better air removal.

Some observations were made upon the hot-water radiator after a run in which the radiator contained air. In this, the pet cock at C was blown in order to ascertain whether the water of condensation could be brought up to as high a temperature and quantity as in the case of complete air removal, when the radiator was entirely filled with water. These tests resulted in bringing the quantity and temperature of the water of condensation up to substantially the same points as in the complete air removal tests.

The coefficients of transmission with varying percentages of air removal were plotted on the diagram and serve to show the comparative efficiency of the radiator at any percentage of air removal.

These tests have not been of sufficient number, nor run under sufficiently accurate conditions to warrant any definite conclusions. The source from which the steam was derived was such that it seemed to have considerable air in it, and the amount of air seemed to vary at different times. The condensation returns of the building are not used for boiler feed, due to the fear of oil. This necessitates the use of city water, and it is their practice to use considerable kerosene oil in order to keep the boilers clean and free from scale.

The radiator was located near a window, from which the leakage varied somewhat in accordance with the outside wind and weather conditions. In some of the later tests the temperature of the air underneath the radiator was taken. This temperature seemed to be an indication of the air leakage through the window, being always lower at times of high-wind pressure.

The pressure of the steam was regulated by a back-pressure valve and varied in proportion to the service load of elevators and lights. Tests such as these should be run with steam made from a boiler feed of distilled water, in order that the steam may be free from air and also from other gases due to the mineral or vegetable matter or oil in the boiler feed. The testing ap-

paratus is now so arranged that air may be injected into the radiator in known quantities, in order to test the efficiency of thermostatic devices in removing it.

It seems reasonable to presume that a close study of this subject might increase the general efficiency of radiation, and perhaps especially of hot-blast radiation, which has been notoriously bad in the past. This might result in a considerable saving, especially where very high temperatures are required by the use of exhaust steam under nominal pressure.

CCLXXXVIII.

REPORT OF COMMITTEE ON HEATING GUARANTEES.

Your committee appointed at the last annual meeting to consider the question of guarantees for heating and ventilating apparatus, who should give them and what they should cover, have given much thought and careful consideration to the subject, and reported at the 1911 summer meeting, in Chicago, in a number of letters from the individual members of the committee, which, while coming from consulting engineers, members of our society, in all sections of the country, were remarkable for their unanimity of opinion.

DURATION OF GUARANTEES.

Your committee would recommend that the designer of apparatus should be considered responsible for the results to be obtained by its use, provided it is installed and operated as designed and intended; and that the contractor should only be held responsible for the installation of the apparatus in the time agreed, with materials specified, in exact conformity with the design and specification, and such materials and labor as he may furnish in placing the apparatus, and that any guarantee which the contractor may be called upon to give, covering the installation, completion and materials and labor furnished, should not extend for a longer period than one year from the time of completion and permanent operation of the apparatus.

The question of what guarantee or assurance, if any, the designer should give the owner is one that would depend somewhat on existing conditions. If it were in an old building and the designer was thoroughly familiar with its construction, exposure and tightness, he would reasonably be expected to guarantee the successful operation of his work. If, on the other hand, he were called upon to design apparatus for a building not yet constructed he could reasonably assume that the building

would be well constructed, and any defect in the construction of the building which interfered with the successful operation of the apparatus designed by him for a well-constructed building should be chargeable to the architect, owner or building contractor, and not against the designing engineer.

As our report was formulated largely by correspondence and the committee as a whole has not had an opportunity of meeting together, we give below the views of the various members of the committee as expressed in their letters:

REASONS FOR GIVING GUARANTEES.

"My opinion has always been that an expert in our line should take on all responsibility that he can reasonably claim, as it conduces to his dignity and commands respect for his work.

"To put out plans and specifications without fully guaranteeing them places the designer in the position of being only a suggester, and his work is open (if the contractor pleases to pass adverse judgment on it) for the owner to grant changes and substitutions that defeat obtaining work that will give the best results and will, in time, mark the designer as not essential, and all because the contractor can claim that he alone is the responsible party and, as such, he should be allowed to make alterations in the design and changes in the materials without restraint.

"Increased remuneration should come with added responsibility. I wish our society would adopt a broad and definite form of guarantee and encourage its use by all members."

"The heating and ventilating engineer should assert himself in the most positive manner, be responsible for his work in every feature and sustain his position by every reasonable assurance and guarantee that his work is everything that it is presumed to be—correct, efficient and complete—and that he will hold himself in the same position that any professional man should do behind his work and figures. The heating and ventilating engineer should be in every sense of the word a 'sure enough engineer,' and alone should be responsible for the success or failure of his own scheme, design, estimate or arrangement that is included in his plans and specifications."

"In the majority of instances there are three persons concerned, namely, the owner of the building, the contractor to

install the plant and set it in operation, and the consulting or advising engineer. Occasionally the contractor assumes the office of the consulting engineer, but that is a situation which I think is not contemplated in this instance.

"The owner may be presumed to be ignorant of heating apparatus and also ignorant of trade customs. If he is wise he will call in a consulting engineer, whose duties will be to examine the building to be heated and take note of its location, exposure, etc. The engineer will then prepare plans and specifications with respect to the specific object under consideration, and upon these plans and specifications contractors are invited to submit proposals for the work to be done in accordance with them.

"Clearly, then, the engineer should be responsible for his plans and specifications, and the contractor can only be rightly held for labor and material and the installation as a whole in accordance with the engineer's plans and specifications. If, however, the engineer has been led to think that for such and such a job Mr. Quick Steamer's boiler is to be preferred, then he may rightly include in the contract the specific guarantee of that particular apparatus with respect to performance as well as capacity and installation generally. Or should he conclude that for some particular case the 'Talkwell' vacuum system of heating should be employed, he may very properly ask Mr. Talkwell to guarantee specifically the particular system in every respect.

"It is manifestly unjust, however, for any engineer to expect a contractor to shoulder the burden of the engineer's ignorance, laziness, or any other shortcoming peculiar to the engineer in question. As a matter of fact, the engineer, if he is worthy the name, will plan and specify only that which he knows or which he has good reason to believe will be suitable for the particular installation with which he is concerned. And after that comes the invitation to competent and desirable contractors to bid upon the work set forth, all of which should be duly followed by a suitable form of an equitable contract.

CAREFULLY PREPARED PLANS A PROTECTION.

"A contractor dealing with a so-called engineer can only be rightly held for the performance of his contract and its included

guarantees, whatever they may be. And if the engineer would avoid disputes, loss of dignity, etc., he will see to it that his plans, specifications and contract are all clear and plain, and that they say and mean just what he desires to say and mean. Vague, incomplete plans and slipshod contracts open the way for all kinds of troublesome sequences. On the other hand, well-thought-out plans and specifications, with an equally carefully written contract, with a real engineer behind them, leave no room for questioning.

"It is all simply a matter of some particular person or persons getting busy and doing that which they undertook to do."

LIMITATIONS OF GUARANTEES.

"In the writer's opinion, the usual heating guarantee is too broad from a legal standpoint, and from a professional standpoint the designing engineer is relieved of responsibility which he should really want to assume; hence, I would say that the guarantee should be limited to material, workmanship and replacing of defective apparatus during a period of one year, which defect is due to imperfection in material or workmanship as specified, and not caused by carelessness or improper operation.

"On the other hand, the plans and specifications should be very clear as to the requirements so that when the contract is signed the chance for misunderstanding is reduced to the minimum. In other words, I would advocate omitting from the usual guarantee where the system is designed by an architect, consulting engineer or others in capacity of engineer, the clauses referring to perfect operation of the apparatus, circulation of steam and maintaining a certain degree of temperature. With a properly designed and properly installed system there should be no question about these features and the responsibility would be borne by all parties concerned according to their various relations to the installation.

"This change, in my opinion, would raise the standard of engineering and would result in a better class of work than is obtained where the contractor is allowed to alter plans and specifications or suggest changes which would detract from the professional standing of the engineer."

GUARANTEES OFTEN UNFAIR TO HEATING CONTRACTOR.

"The heating contractor should not be required to give a capacity guarantee for apparatus designed by another, provided, of course, it has been installed by him in a proper manner according to the intent of the designer, and conversely that the responsibility then rests with the designer.

"The question is a very broad one, and whatever recommendations are made by the society must necessarily be broad in their scope in order to reconcile as much as possible the various opinions held by members of the engineering profession and the trade.

"I have always considered the usual '70 deg. in zero weather' guarantee exacted of the contractor as unfair to him when he installs an apparatus strictly in accordance with the design furnished him by another, and when this clause is modified, by making it optional with the contractor of increasing the capacity, if in his opinion the sizes called for are not sufficient, I consider this amounts to a confession of weakness on the part of the designer and tends to put him in the 'position of being a suggester only,' as so aptly stated by one of the committee.

TEST METHODS FREQUENTLY UNFAIR.

"The methods often applied to determine if temperature guarantees have been fulfilled are also inadequate, indefinite and oftentimes unfair. The method of testing room temperatures in mild weather and from this calculating the probable temperature in zero weather is not conclusive evidence that a temperature guarantee has been fulfilled, not only because the practical value of such tests is questionable, but also because air leakages and wind pressures, occurring under actual winter conditions, may completely upset any calculations based on such tests.

"The method of withholding a percentage of the contract price pending a tryout of the apparatus throughout a heating season is manifestly unjust to the contractor and often results in added first cost to the owner, as the contractor must cover himself for any possible loss due to long-deferred payment for his work.

"The question of air-leakage, above referred to, brings up the subject of faulty building construction, which is a matter entirely

beyond the control of either the designer or the contractor, and it does not seem fair to hold either party responsible for proper heating results when faulty construction exists.

"Improper operation of the plant is another matter which should modify a guarantee, as we all know what poor management can do to an otherwise well-designed and properly constructed apparatus.

"There are other guarantees often exacted, the fulfillment of which the owner may not so readily determine for himself, as happens in the case of room temperatures, and I doubt not that in many instances the owner is left in ignorance of whether he is getting out of his apparatus the performance he has been led to expect by these guarantees. I refer to guarantees covering air quantities delivered to and exhausted from the rooms, the relative humidity and percentage of dust removal, effected by humidifying and air-washing apparatus, and the like. These matters can only be determined by tests, and it may be that the subject of tests might well be considered in its relation to guarantee standards.

TWO MAIN PROBLEMS.

"It seems to me that the two main problems for solution are:

"First.—Should a guarantee be exacted of the engineer, and, if so, what nature and how should it be arranged?

"Second.—What should be included in a guarantee exacted of the contractor and how may it be enforced? It will take time and much consideration and discussion to solve these problems, and I can do no more than offer briefly a few thoughts for consideration.

"In regard to the first question, it may be argued that an engineer of established reputation and proved ability is a guarantee in himself covering any work designed by him, else he could not continue in business successfully.

"In regard to the second point, I believe the contractor should be responsible for his workmanship in every particular, including, consequently, noiseless and efficient circulation, and noiseless operation of rotating or reciprocating apparatus, and also that he should assume all guarantees required of and made by his sub-contractors.

"In any case I think that faulty building construction and

improper operation should be in some manner provided for as modifications of heating guarantees."

One of the members of our committee, wishing to get the opinion of others on this subject, formulated and forwarded the following seven questions to prominent heating engineers in this city who are engaged in contracting for as well as designing heating and ventilating apparatus:

QUESTIONS ASKED OF CONTRACTING ENGINEERS.

First.—Should the contractor guarantee the proper heating of a building when he installs radiation as laid out by the architect or engineer?

Second.—Should the contractor be required to change piping in order to effect the proper working of the system to comply with the guarantee when the piping has been installed according to plans?

Third.—In your opinion, is a period of one year a reasonable length of time from date of completion in which the contractor should make good any defect in apparatus installed by him?

Fourth.—When work is installed in strict accordance with plans and specifications, in your opinion can the guarantee be made operative and hold in case of failure of the apparatus?

Fifth.—Do you know of a case where the contractor has been held liable under the guarantee for failure of the apparatus and required to remove it as a consequence?

Sixth.—To what extent should the contractor be held liable or responsible for special apparatus installed by him under requirement of specifications or where he has had no alternative in the matter of selections?

Seventh.—How would you word a guarantee which you would agree to comply with literally, incorporating in it the operation of apparatus, circulation of steam and defective material?

He received the following replies, three of which were from members of this society:

"I have yours of the fifth, and note your questions and would answer them concisely as follows:

"First.—No.

"Second.—Not if he called the architect's attention to defects of plans before doing the work.

"Third.—Yes.

"Fourth.—Answering your questions as literally put—No.

"Fifth.—No.

"Sixth.—The contractor should not be held in the least degree responsible under these conditions, and this is a very important matter to bring squarely before the society, as legally or morally there can be no responsibility under these conditions."

"Replying to your favor of the fifth inst., wish to advise you as follows:

"First.—In no case should a contractor guarantee the effectiveness of a heating plant unless thoroughly gone over, checked up and approved to be correct in his own estimation.

"Second.—It would not be proper for the heating contractor to change the system of piping or radiation in any way if mechanical drawings are made by the architects and engineers, and he should carry the same out fully, and the architect and engineer should be held responsible and not the contractor.

"Third.—One heating season should be entirely sufficient to fulfill any guarantee.

"Fourth.—This is a legal point which could only be settled in some court of justice, in my mind, as it would involve so many fine points, and the contractor should familiarize himself with the plant if such a clause covering guarantee was embodied in the specifications or contract.

"Fifth.—On several occasions, but more from a business standpoint than a legal one, as it reflects badly upon any heating contractor to have work constructed in an unsatisfactory manner.

"Sixth.—The contractor should not in any way be held responsible for the efficiency or guarantees which may be required on special apparatus specified exclusively by the architects and engineers.

"Seventh.—In order to guarantee the complete installation of apparatus and the successful operation of same I would word the guarantee as follows: 'We hereby guarantee that all labor and material used in the construction of the apparatus is first-class in every respect and that the heating apparatus is capable of heating the building to the temperature required. Guarantees on special apparatus should be very clearly written, giving the size and make of the apparatus, the efficiency, etc."

"In reply to your communication of December 5, with refer-

ence to the subject of heating guarantees, we are pleased to give you herewith our opinion as to the proper answer to the various questions asked, to wit:

"First.—No.

"Second.—No.

"Third.—Yes.

"Fourth.—We have never had occasion to test this clause in a court of law. We are of the opinion, however, that the courts would not uphold such a guarantee. However, as you have been on the 'other side of the fence,' you are quite familiar with architects' methods in getting the contractor to shoulder these responsibilities.

"Fifth.—We know of cases where the contractor has been compelled to install additional radiation at his own expense.

"Sixth.—Not any.

"Seventh.—The wording of a guarantee should be dependent upon the conditions. Where the engineering is done by the contractor he, of course, should be willing to guarantee the perfect operation of the apparatus and circulation of the steam. Where an architect or a consulting engineer is employed to do the engineering, the contractor should only be compelled to guarantee the material and workmanship against defects for a period of one year from date of completion of the contract. In case of defective material the manufacturer should be held liable by the contractor, not only for the defective material, but for the labor necessary to replace it as well."

"Replying to yours of the fifth, in which you are making an effort to gather some views from heating contractors on the subject of heating guarantees, wish to answer your questions as per the following:

"First.—It is our opinion that a contractor should not be asked to guarantee the proper heating of a building where he installs radiation as laid out by an architect or engineer.

"Second.—A contractor should not be required to change the piping in order to effect the proper working of a heating system to comply with the guarantee when the piping has been installed according to plans as may have been prepared by an architect or engineer. However, other clauses in the specifications might make it necessary for the contractor to go on record and install the piping under protest, if he at that time is satisfied that by

such installation the system will not operate properly to comply with the guarantee.

"Third.—It is our opinion that one year is a reasonable and proper length of time for a contractor to make good any defect in apparatus installed by him, excepting the usual wear and tear.

"Fourth.—It is our opinion when work is installed in strict accordance with plans and specifications furnished by an architect or engineer, that the guarantee cannot be made operative or hold in case of failure of apparatus, providing the contractor has protected himself by making such installation under protest and placing himself on record at the time of such installation.

"Fifth.—We do not recall at this time a case where a contractor has been held liable under the guarantee for failure of the apparatus and required to remove it as a consequence to question four.

"Sixth.—A contractor should not be held liable or responsible for special apparatus when he had no alternative.

"Seventh.—A contractor should be asked to guarantee only the workmanship and defective material where plans and specifications are drawn by an architect or engineer.

"Where a contractor prepares his own plan and specification, he should guarantee the plant in its entirety—that is to say, proper operation, free circulation of steam, temperatures as called for in specifications, and to replace defective material, excepting the usual wear and tear for a period of one year."

Respectfully submitted,

WM. M. MACKAY, *Chairman*,
FRANK C. GOFF,
THOMAS MORRIN,
C. E. PEARCE,
JOHN D. SMALL,
Committee on Heating Guarantees.

TRANSACTIONS

OF THE

SEMI-ANNUAL MEETING,

Detroit, Mich., July 11, 1912.

CCLXXXIX.

SEMI-ANNUAL MEETING, 1912.

First Day—Morning Session.

(Thursday, July 11, 1912.)

The meeting was called to order at 10.00 o'clock by Vice-President Hale.

Chairman Hale: In the absence from this country of our honorable President, John R. Allen, the responsibility of acting in his stead has fallen upon me, whom you elected First Vice-President of the Society in January last.

In July, 1904, the seventh semi-annual meeting was held in this city, when the Honorable Andrew Harvey was president of the Society. At that time the membership consisted of but 189 active, 1 honorary, 14 associates, and 5 juniors, or a total of 209; whereas we now have upon our rolls 397 active, 11 honorary, 31 associates, and 15 junior members—a total gain of 245 members in eight years.

Eight years have passed, in which much has been done toward the advancement of the science of heating and ventilation. Some who were with us then have departed and many new members have joined our ranks, but still we seem to discuss the same subjects, ponder over the same problems, without getting down to very many actual standards. Research is being made into the field of ventilation and we hope that the physiologists will soon set for us a standard upon which they agree is the proper basis for our calculations. Experiments are now being made to determine the proper method of delivering heated and purified air into a schoolroom or auditorium, and the subject as to the proper relations between humidity and temperature is a common topic of conversation when engineers come together.

These subjects and many others are to be considered at this

meeting and the results of our deliberations will become part of our records and go down for the future guidance of those interested in the things relating to the science of heating. This organization was formed for the interchange of ideas on the subjects relating to the science of heating and ventilation, and each member is morally obligated to give freely of his fund of information so that others may be benefited thereby, or, as more perfectly expressed by Sir Francis Bacon:

"I hold every man a debtor to his profession, from which as men do of course seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and an ornament thereto."

In the absence of Prof. John R. Allen, our President, we have a communication from him from Constantinople. This is in the form of a paper on the subject of "Heating in Turkey."

The paper was read by Vice-President Hale.

Secretary Macon read the list of new members elected at the last ballot.

LIST OF NEW MEMBERS.

Auguste Beaurrienne	W. J. Kline	Herbert Muth
John F. Carney	F. S. Lamson	P. J. Newkumet
P. H. Fabricius	William Lees	R. W. Otto
C. N. Flagg, Jr.	F. J. Lennox	Ralph C. Taggart
W. A. Gates	M. L. Longworth	F. H. Valentine
C. W. Haensel	William N. McKenna	

Associate Members

Walter Cambridge	Chas. F. Chase	W. G. W. Turno
	A. A. DuMond	

Junior Members

W. S. Dickinson	Herbert K. Lees	J. E. Miller

Chairman Hale: Communications from the chapters of the Society are next in order, and I will call upon one of the members of the Illinois Chapter to submit their report in the absence of their secretary.

Mr. Lewis: I have a letter from Mr. W. L. Bronaugh, Secretary of the Illinois Chapter.

CHICAGO, July 9, 1912.

The American Society of Heating and Ventilating Engineers, New York City.

Gentlemen: We shall not attempt to make a complete report of the work done by the Illinois Chapter up to the summer meeting, but would summarize the work done since our annual report in January.

One of the largest meetings held by this Chapter was held on January 8. The discussion on the work of the Chicago Ventilation Commission was the topic for consideration and the Chapter had the officials of the Department of Health, Dr. Evans, Members of the Board of Education, Dr. Tonney and a number of prominent engineers of the city their guests. This was the most successful meeting of the year.

The topic for discussion for the February meeting was the question of humidity. This proved to be a very interesting and instructive one to all members. The committee's report was read and brought out a most liberal discussion.

The topic of discussion for the March meeting was a series of tests and report was read by Mr. Hogan. A number of tests and fan ventilation of heating plants were brought out and especially one relating to the heating and ventilation of moving picture theatres, which was very pertinent at this time on account of the work of the Ventilation Commission of the Department of Health.

The topic of discussion for the April meeting was a test of the plant of the Northwestern University. This topic, together with the report for February meeting, are the basis of papers being read at the summer meeting of the Society.

There was no particular topic assigned for the May meeting but impromptu discussions on the modern methods for school ventilation came up and plans of the Omaha High School, Toledo High School and several schools of the Chicago Board of Education were presented.

These were all interesting and especially the discussion by Mr. Patterson as to the work accomplished by the public school system of the city of Chicago.

We believe that this year's work has been very instructive and the manner in which the members have responded in attending has been very gratifying. The Chapter is well off

financially and we feel that the members have been benefited by the monthly meetings that have been held during this past season.

Yours very truly,

W. L. BRONAUGH,
Secretary.

Chairman Hale: The report of the Illinois Chapter will be accepted and placed on file.

The report of the New York Chapter was read by Mr. Graham.

REPORT OF THE NEW YORK CHAPTER.

The New York Chapter of this Society desires to make the following report:

In January the Chapter made a report showing that at that time the chapter had a total membership of 64.

A regular monthly meeting was held on February 13 in the Engineering Societies' Building. The subject of discussion was factory ventilation in New York state. The discussion was opened by Dr. C. T. Graham-Rogers, who was followed by Mr. D. D. Kimball, chairman of the New York state committee on Compulsory Ventilation, and by a large number of the members. It was voted that the chapter delegate the committee on Factory Ventilation in New York state, appointed by the main body, to represent the chapter and use every effort to co-operate with the committees of other organizations to bring about practical legislation relative to factory ventilation.

A dinner was held by the members at the Hotel Hermitage, Tuesday, March 12. Thirty-three members and guests were present. Mr. F. G. McCann, of the Board of Education, gave an extremely interesting address on the ventilation of the New York public schools which was quite generally discussed. He was followed by Mr. J. A. Donnelly, who spoke on the subject of the time element in starting up house heating boilers.

The April meeting of the chapter was held in the Engineering Societies' Building on April 9. Mr. J. I. Lyle gave a lecture at this meeting on air washers and humidity control, making use of stereopticon views to illustrate the subject, and Dr. Wm. F. Colbert, of Philadelphia, made a short address on ventila-

tion, quoting extracts from an address made by Dr. W. A. Evans, former Health Commissioner of Chicago, before the Midland Club. The rest of the meeting was devoted to the discussion of these subjects.

At the May meeting a dinner was held at Keen's Chop House on May 14. The speaker of the evening, Mr. Wm. J. Baldwin, made an address on "Steam Fitting and Ventilation Forty Years Ago."

Other addresses were by Mr. D. D. Kimball, on "Ventilation with Special Reference to the Architect," by Mr. H. J. Barron, on "As I See Things To-day," by Mr. J. A. Donnelly, on "The Needs of the New York Chapter," and by Mr. Frank K. Chew, on "Conservation of Energy and Concentration."

Since its inauguration the New York Chapter has been doing missionary work which we believe will be of great benefit to the Society. We have increased, and are continually increasing, the membership of the parent body which is brought about by engineers desiring to become members of the chapter.

The chapter was the first to take up the subject of the ventilation of moving picture show places and to point out the necessity of having these places correctly ventilated. Since that time the parent body has appointed a committee to report on this subject.

The chapter has also appointed a committee to help along the cause of factory ventilation in New York state.

Believing that the interest of ventilation would be greatly advanced by bringing the matter before the people in the shape of lectures in the schools and engineering societies in the city, the secretary wrote to the Y. M. C. A., Harlem Branch, City of New York, which is carrying on a course in heating and ventilation, asking them to appoint a date in March or April when this subject could be discussed. Upon receiving a favorable reply Mr. D. D. Kimball, one of our members, delivered a lecture on the subject of ventilation on April 11 which was very well attended. It is hoped to have lectures throughout the city and vicinity during coming meetings of the New York Chapter.

The secretary has undertaken to compile a list of consulting, heating and ventilating engineers, and desires to submit at the present time a partial list of such engineers throughout the

country. This list comprises purely consulting, heating and ventilating engineers.

The membership of the Chapter is as follows: 2 honorary members, 66 members, 3 associate members, and 2 junior members.

The report of the Massachusetts Chapter was read by Mr. Whitten.

REPORT OF MASSACHUSETTS CHAPTER.

The first meeting of the Massachusetts Chapter was held at the office of the Society at the Engineering Societies' Building, New York City. H. W. Whitten was elected temporary President, and D. S. Boyden, temporary Secretary. A committee on constitution and by-laws, of which Wm. G. Snow was chairman, and on nomination of officers, of which A. B. Franklin was chairman, were appointed.

The second meeting was held February 8, at office of Cooper & Bailey, 89 Franklin street, Boston. The following officers were elected:

President, Wm. G. Snow.

Vice-President, Frank Irving Cooper.

Secretary, Herbert W. Whitten.

Treasurer, Wm. T. Smallman.

Managers, A. B. Franklin, Jos. A. Moore, D. S. Boyden.

Mr. Snow reported a constitution and by-laws which were adopted, subject to the action of the Board of Governors of the parent body.

Meetings have been held on the second Tuesday of each month up to, and including, the month of May. The March and April meetings were held at the Boston City Club, and the May meeting at the Elks' Club. Each of these meetings was preceded by a dinner and was pleasant and instructive. The March meeting was devoted to the discussion of "Ventilation in Relation to Health." The April meeting: "Review and Discussion of Work of the Committee on Schoolhouse Ventilation," F. I. Cooper, Chairman. During this discussion Mr. Chas. F. Eveleth exhibited some graphic charts showing results observed at a testing station. Mr. James Watson, a member of the Council of the British Society of Heating and Ventilating Engineers, was a guest at this meeting.

The May meeting was devoted to the discussion of the Commercial side of Engineering, and the subject was discussed at length, with profit.

The Chapter consists of fifteen charter members, with one application for membership.

We look forward to an interesting and instructive year and expect to increase our membership materially. We have no debts and a balance in the treasury.

Respectfully submitted,

WM. G. SNOW, President.

H. W. WHITTEN, Secretary.

Chairman Hale: The next item on our program is the interim committee reports. The first is the Subcommittee on Code for Testing House Heating Boilers, of which Mr. E. A. May is chairman.

Mr. May: Mr. President, that committee has been appointed recently and they have had no opportunity to get together.

I want to take this opportunity to ask the members of the Society if they have any suggestions on the testing of house heating boilers that they will feel free to write me at Chicago, and give those suggestions, because the committee should have the advantage of every bit of information they can get.

And another thing I would bring out at this time. It seems to me, as committees are appointed from time to time on the same subject, there should be an accumulation of material. There seems to be none, although there have been several committees on the code for testing boilers, there are no data available of the work of those committees, other than their tentative report; and therefore this new committee has to go over the field that they have threshed over and thrown aside material at being not competent, and we have to do that all over. Now it seems to me that any committee appointed by the society should leave its records as a part of the record of the society, and not to be thrown away after the report is made; and I believe that is pertinent to any committees, and I would like to bring it out now because I feel the lack of all that information which has been accumulated and is not now available.

Chairman Hale: The Chair quite agrees with you, Mr. May, in that respect, and an attempt will be made to get from previous

committees such information as we can on the subject of heaters, and see that you get it after it comes to us in proper shape. Does any one wish to express his opinion on the matters spoken of by Mr. May? If not we will accept his interim report.

There is a subcommittee of the Committee on Tests, on Standard Outside Minimum Temperatures, of which Mr. R. P. Bolton is chairman, this committee is made up of nine members selected from the most distant parts of the country, from New York to San Francisco and from the north to the south, and a portion of the interim report has been made by Mr. Bolton, which is in the hands of the Secretary, which he will read to you now.

REPORT OF SUBCOMMITTEE ON STANDARD OUTSIDE MINIMUM TEMPERATURES.

Your subcommittee presents a report of progress and anticipates the presentation of a much more complete statement upon the subject assigned to its attention at the annual convention next January.

Since the appointment of the Committee, the work of which is necessarily conducted by correspondence, the Chairman has suggested to each of its members the collection of a local record of temperature variations during a complete heating season, to be later supplemented, if possible, by similar records over a number of such seasons.

Following out the method pursued by the Chairman in compiling comparative data on this subject in New York City, each committeeman has been asked to obtain records from the local weather department or any other local source, of the hourly variations, so that a curve can be plotted for the average hourly temperature variations for each month of the heating season. The purpose of this method is to bring out not merely the minimum temperature on any one occasion, but the period of the day in which that occurrence is found to take place. One of the members of the Committee, Mr. Thos. F. Morrin, of San Francisco, has secured this information, through the courtesy of Prof. A. McAdie of the United States Weather Bureau of San Francisco, and in order to illustrate to the members of our Society the line of information to be derived from such

data, prints are submitted herewith showing the mean hourly variations of temperature for each month during the heating

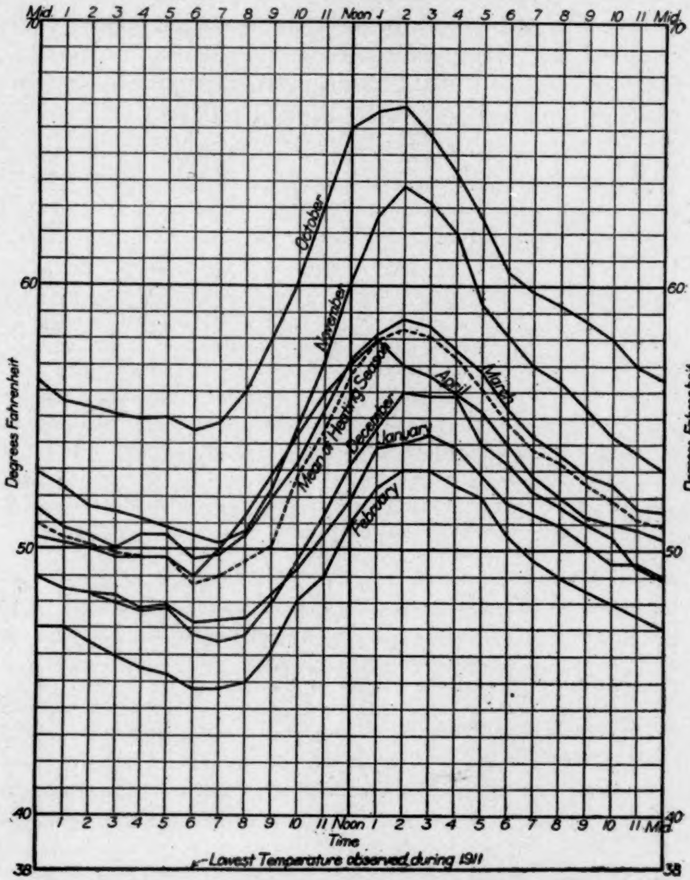


DIAGRAM D.—SHOWING HOURLY VARIATIONS OF TEMPERATURE DURING HEATING SEASON IN SAN FRANCISCO.

season, in the district of San Francisco—diagram D. An observation of this set of curves shows that the same general characteristics are found to exist in temperature variations, as have been noted in the New York observations above referred to—namely, that the lowest temperatures prevail during the earliest hours of the day, and that a sharp rise takes place after

7 o'clock in all of the curves. It is interesting to observe that the lowest observed temperature during the season of 1911

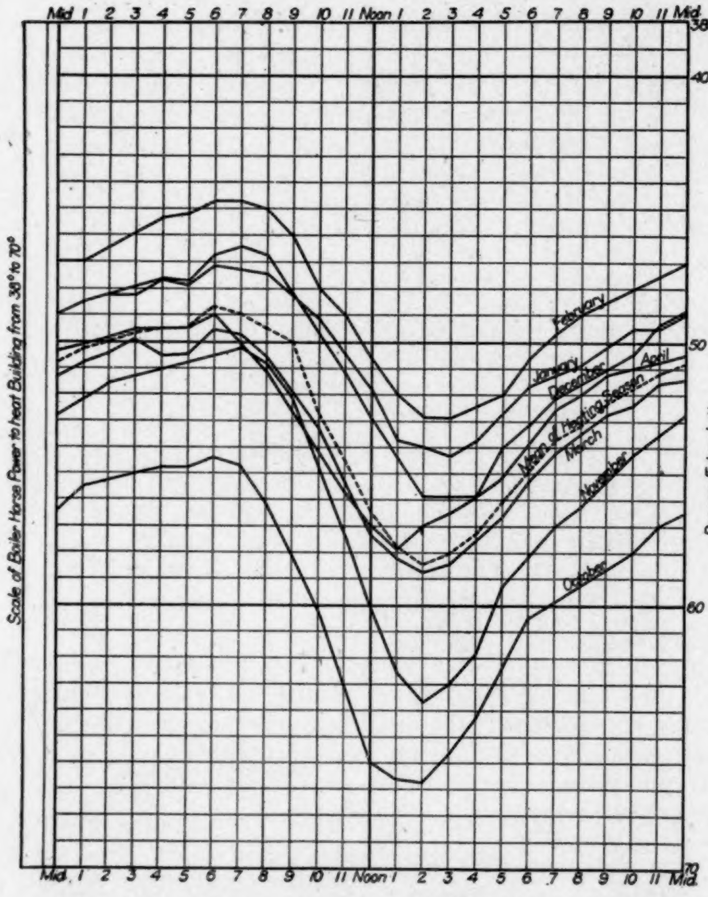


DIAGRAM D-1.—SHOWING BOILER HORSEPOWER REQUIRED TO HEAT BUILDINGS FROM 38 TO 70 DEG.

thus recorded is 38 deg.—a very isolated and temporary occurrence.

These curves are reversed upon diagram D-1 and are placed upon a scale divided into tenths which can be utilized as a scale of boiler horsepower required to heat a building from the

minimum of 38 deg. to 70 deg., thus affording the means of determining the average monthly work to be done in the heating of a building, and the variation of that work between the hours of the night and those of the daytime.

The important element of wind movement has not been disregarded, and observations will, it is hoped, be available from each of the committeemen's districts, throwing some light on wind directions and velocities. In the case of San Francisco, it is observable that the average hourly velocity for the season of 1911 was 8.2 miles, which accords very closely with the mean recorded for air movement in the vicinity of New York City.

It is hoped that the committee will be able to bring together a number of similar sets of observations which will afford a basis for the collection of similar data covering the whole country, which may eventually be summarized in climatic sections where practically similar conditions are found to exist, so that the entire country may be mapped from the point of view of heating requirements.

REGINALD PELHAM BOLTON, Chairman.

Chairman Hale: The report will be elaborated on at the annual meeting. This is only a portion of the report that was made by Thomas Morrin, of San Francisco, and it is our belief that when the complete report is seen it will be a very valuable addition to our literature.

Mr. Soule: I would like to make a suggestion that the humidity readings be taken at the same time as the temperature and wind velocity readings are taken, and the wet bulb thermometer and relative humidity. These seem to be very valuable data.

Chairman Hale: It will be done. The next report is the report of the Subcommittee on Ventilation Standards of Motion Picture Theatres, of which Mr. F. T. Chapman is chairman.

Mr. Chapman: Your committee has had two meetings and has gone into this question very thoroughly and has mapped out considerable work, but we had not expected that a report would be required at this meeting. So if you will accept a report of progress we will see that you get a full report at the annual meeting.

Chairman Hale: The Committee on Tests, Mr. L. C. Soule, chairman.

Mr. Soule: This committee had just been appointed. We have had no meetings yet, but we hope to make a collection of some valuable data during the year. I believe Mr. Donnelly has some suggestions to make regarding some of the tests which he has made.

Chairman Hale: Will Mr. Donnelly report upon these tests?

Mr. Donnelly: Mr. Chairman, in Rochester I ran across a series of tests that had been made to ascertain the amount of steam required to heat a group of factory buildings, with live steam in some cases and exhaust steam in other cases. Those tests are not like others that have been made on this line, with live steam on Sundays or holidays and nights and exhaust steam in the daytime, but have been on tests of several days with live steam and several days with exhaust. The curves and data from these tests show opposite results from that which we have usually had reported in our meetings; that is, they show that more coal was burned while the engines were running and producing light than while live steam was used for heating, the engines not running. I think that this series of tests would repay investigation. Mr. de Wolf, who is the engineer for the Rochester Railway, Light and Power Co., has looked after this, I think, more or less, at station 35 in Rochester, and I would recommend it to the Committee on Tests for investigation.

Another collection of data has come through a new associate member of the Society, Mr. Charles J. Jackson, of Chicago, who sent to me a record of tests of radiator steam traps conducted at the State Department of Engineering, Sacramento, Cal., by E. D. Griffith, State Engineer. I would recommend that this matter be submitted to the Committee on Tests for investigation, criticism and suggestions, and that a recommendation be made as to a standard method of conducting such tests to the Committee on Standards.

Chairman Hale: Proper action will be taken on Mr. Donnelly's suggestion, to have the Committee on Tests look into these two features that have been spoken of.

Compulsory Legislation is the next on the committee list, and

we will be glad to hear from Professor J. D. Hoffman, who is the general chairman of the Committee on Compulsory Legislation.

Professor Hoffman: Mr. Chairman, it is apparent to all of us, after reading over the laws of various states on Legislation for compulsory ventilation, that there is quite a wide variety of practice and not a great deal of agreement, so it has occurred to our committee to standardize some of the essentials and propose them to the Society for consideration. The committee has been working along this line for the past year. The report was to have been prepared and submitted at the last annual meeting but for reasons known to the Secretary and to the President it was laid over for a year. We now hope that will be in shape for the next annual meeting.

Secretary Macon: The Society has a letter from the National District Heating Association. (Reads.)

LETTER FROM NATIONAL DISTRICT HEATING ASSOCIATION.

Greenville, O., July 5, 1912.

American Society of Heating and Ventilating Engineers:

Gentlemen: The National District Heating Association, at its Fourth Annual Convention, held in the city of Detroit, Mich., directed me, as the Secretary, to invite your Society to appoint a committee of five from your number to act in connection with a committee of five from the National District Heating Association and to work along educational lines in heating and ventilating.

Should your Society appoint such committee, the National District Heating Association will take pleasure in appointing a committee of five from their number to carry on this work.

I am, very respectfully yours,

D. L. Gaskill, Secretary.

Chairman Hale: The members have heard this suggestion made by the Secretary of the National District Heating Association and it is now proper for any one to discuss the matter that may see fit.

Mr. Whitten: I attended the convention of the National District Heating Association two weeks ago. Among the things

that came up was a report of a committee on station records, and these records seemed to be very incomplete. I was particularly interested, however, in a paper which was read by G. E. Chapman, District Superintendent of the Public Service Company of Northern Illinois, Oak Park, in which the method of keeping records was somewhat unique, in that he had a homemade apparatus whereby he could register not only wind velocities but wind pressures, and he found that the wind had a great influence on the station output. The apparatus was a sheet of aluminum hung at the top so that it would swing as the wind struck it, there being a weather vane on the upper part; on its axis at the top was a small pulley, over which a cord was passed and went down through a piece of gas pipe into the engine room and was there connected to an old steam gauge they had taken the works out of and connected directly to the barrel, so that as the cord lowered the pointer traveled around the face of the dial. This dial was subdivided into four portions, corresponding with wind velocities, but not exactly so. They registered the pressure as well; and the subdivisions were from practically nothing to five miles, then from 5 to 15, 15 to 25 and from 25 up. And they varied the pressure and the temperature of the hot water which they circulate through their heating plant in accordance with the temperatures outside and the wind velocity or the wind pressure, as registered by this homemade apparatus.

At Crawfordsville, Ind., a somewhat similar idea was in use, although they used, I think, a Belford anemometer; and a Bristol anemometer is also in use in Columbus. In these station records they keep the record of the wind and temperature. They purpose now, as I understand it, to keep parallel records of temperatures, wind movements or wind pressures, which seems to be more essential, humidity and the condition of the barometer, keeping all of those, and in addition to that a parallel record of the output, with the size of the plant noted, and any additional information along that line. They propose also to keep records of individual typical buildings, in the hot water systems, putting on a meter and a flow and return thermometer, and keep those in conjunction with these same records.

Having collected this mass of data there did not seem to be any one in that association who felt competent to analyze it; that is, to find out just what all this meant; and on that account

it was voted to notify this Society to appoint a committee to analyze a season's record from several of these stations and see what they could deduce from it.

Mr. Whitten: It seems to me that there will be an opportunity for this Society to obtain possession of data which as individuals it might take us years to collect; and if those records are kept faithfully, especially the records on individual typical buildings, like factories, for instance, that are equipped with concrete roofs and steel sides and all the modern inventions, that we are none of us very familiar with, if we could have the season's observations of the weather conditions and the output required to heat those buildings, we will get information in a comparatively short time that it would otherwise take us a long time to get, and then if the data could be analyzed by some of our experts, I think that their report on them would be of great value.

Mr. Quay: I move that the matter be referred to the Council to appoint a committee to coöperate with the National District Heating Association at its request.

The motion was seconded, put to a vote and carried.

Mr. Mackay: Mr. President, at the annual meeting of the Society last January a committee was appointed on the 1912 United States Standard, for Pipe Flanges and Fittings, and it brought in a report and its report was adopted by the Society, and it has also been adopted by several other bodies, and I understand also by the United States Government. I think it is in order at this time to offer the following resolution:

"Resolved, That the members of American Society of Heating and Ventilating Engineers present at this meeting recommend to its members and all heating and ventilating engineers that they use and specify in their work the 1912 United States Standard Schedule of Standard Weights and Extra Heavy Flanged Fittings and Flanges, as adopted at the annual meeting of the Society in January, 1912."

After some discussion the motion was put to a vote and carried.

Professor Hoffman: I would like to move that our Secretary extend to our absent President an expression of this meeting of the regret that we have that he could not be with us, at the

same time extending to him our thanks and appreciation for the words given in his letter of address.

The motion was seconded and carried.

Chairman Hale: We will now take up the election of the Nominating Committee, which, according to the new constitution and by-laws, is to be appointed by the members at the semi-annual meeting. The committee is to consist of five members, to be elected by the members at this meeting, and to nominate for the office for 1913. Are there any nominations?

Mr. Chapman: I would like to present the following names, with a view of getting a representative committee, Mr. George Mehring, Chicago; Mr. Edwards K. Munroe, of Baltimore; Mr. Joseph Graham, of New York; Mr. Herbert W. Whitten, of Boston; Mr. Charles F. Newport, of Chicago. Other members presented the names of Mr. R. Hill, of Detroit; Mr. Howard T. Gates, of New York; and Mr. D. M. Quay, of Cleveland.

Chairman Hale: The Secretary is instructed to have ballots passed to the members and the vote will be taken while a paper is being read by Mr. Whitten.

Mr. Whitten read a paper on Temperature Equivalents of Wind Velocities.

It was discussed by Messrs. Donnelly, Collamore and Small.

Mr. Pittelkow: The tellers beg to announce the vote as follows: Mr. Whitten, 23; Mr. Newport, 20; Mr. Still, 20; Mr. Graham, 19; Mr. Mehring, 18; Mr. Munroe, 18; Mr. Quay, 11; Mr. Gates, 6.

Chairman Hale: What is your wish in this matter? The constitution and by-laws call for the election of five members of the Nominating Committee, and two names are tied for the fifth place.

Mr. Lewis: I move the Chair cast the deciding ballot.

Chairman Hale: I cast the ballot for Mr. Mehring.

On motion the meeting adjourned till 2.00 o'clock.

First Day—Afternoon Session.

(Thursday, July 11, 1912.)

The meeting was called to order at 2.30 o'clock by Vice-President Hale.

Mr. Donnelly read a paper on "The Time Element in Heating

Apparatus." It was discussed by Messrs. Hoffman, May, Whitten, and Quay.

Mr. J. D. Small read a paper on "Office Practice in Estimating, Heating and Ventilation." It was discussed by Messrs. Hale, Soule, May, Donnelly, Whitten, Quay, Collamore, Lewis, and Williams.

Mr. Lewis read a paper on "Heating and Ventilation of a Mitten Factory." It was discussed by Messrs. Hale, Quay, Whitten, and Donnelly.

Mr. L. C. Soule read a paper on "Humidity in Relation to Heating and Ventilation." It was discussed briefly by Mr. Lewis.

Chairman Hale: The next paper is one written by H. C. Russell, on the subject of "Brick Drying." In his absence the Secretary, Mr. Macon, will read it in abstract. The paper was read in abstract. No discussion.

Mr. Quay opened the discussion on "Upward versus Downward Ventilation for the School Room." The subject was discussed by Messrs. Hale, Lewis, Quay, Chapman, and Williams.

Mr. Feldman's paper, "Ventilation of a Dispensary Building," was read by Mr. Mackay. It was discussed by Messrs. Donnelly, Hale, Davis, Hoffman, and Lewis.

On motion the session adjourned till Friday morning.

Second Day—Morning Session.

(Friday, July 12, 1912.)

The meeting was called to order at 10.30 o'clock by Vice-President Hale.

Mr. F. R. Still read a paper on "Removal of Refuse and Waste by Fans and Blowers." It was discussed by Messrs. Whitten, Weinshank, Hale, Hoffman, Soule, and Davis.

Chairman Hale: I believe Mr. Macon has an announcement or two to make.

Secretary Macon: Our former President, Mr. Andrew Harvey, of this city, is seriously ill. It might not be out of order to pass some resolution directing the Secretary to convey the expression of this meeting of its great regret at his inability to participate in the meeting in his own city.

Mr. Still: Mr. President, I make a motion to that effect.

Mr. Harvey has been in poor health for a long time. He always had a great interest in the Society; in fact, he and I were the only ones in the city for a great many years. I think he would appreciate it very much. The motion was seconded by Mr. Weinshank and carried.

Chairman Hale: The Secretary is requested to send that expression of sympathy and regret to Mr. Harvey or to his family.

Professor Hoffman: Mr. Chairman, we have all experienced an unusual reception here in the city of Detroit. We have had an expression of the hospitable treatment from the members as they have gathered together in little groups. We all appreciate the royal entertainment that we have had. I move that a vote of thanks be extended to the local committee, and also to those organizations that are associated with them for our entertainment, for their very kindly and courteous treatment extended to the members during this meeting. The motion was seconded and carried.

Mr. Lyle read in abstract his paper on "Methods of Automatic Humidity Control for Air Washers." It was discussed by Messrs. Soule, Williams, Ellis, Davis, and Fenstermaker.

Secretary Macon then read a paper by Ralph C. Taggart, on the subject of "Open Windows in Mechanical Ventilation." It was discussed by Messrs. Still, Whitten, Hale, Lyle, Williams, Davis, and Stannard.

Secretary Macon: I have a letter from Charles G. Armstrong, of New York, a member of the Society. (Reads.)

New York, July 9, 1912.

President and Members of the American Society of Heating and Ventilating Engineers.

W. W. Macon, Secretary.

Dear Sirs: For the past six months, we have been engaged in investigating the ventilation problem in the New York Public Schools for the Committee on School Inquiry, Board of Estimate and Apportionment, and have submitted a report upon the same under date of June 27, 1912.

We were assisted by Professors Charles Baskerville and C.-E. A. Winslow, of the College of the City of New York.

This report is the property of the Committee on School

Inquiry and will undoubtedly be made public within a short time, but we would like to present to your Society, a few opinions contained therein.

We believe with Mr. Taggart and other sensible ventilating engineers, that personal equation or human perversity greatly affects the success of a ventilating system.

Any apparatus so designed that windows must be kept closed for its successful operation, is a failure not necessarily because of its mechanism, but because of the psychological effect upon the occupants of the rooms so ventilated.

Quoting from the report, we have,

"With a perfectly balanced system, the windows could be opened or closed at the whim of the teacher and produce the required psychological effect without appreciably disturbing the cycle of ventilation."

After our investigation, we concluded that open window ventilation alone, was decidedly deleterious to the health of the pupils, particularly among New York's congested streets, and that the common practice of blowing air from the street level, unwashed or filtered in any way into the school rooms was even worse, as that produces a concentration of the bad conditions, which prevail in open window ventilation.

As we anticipate antagonism from people for instance, who state that "The thermostat is an invention of the devil," and other such ignorant remarks, which nevertheless have a certain bearing upon the art in general, we would like to ask for an expression of opinion by this Convention upon the "open window" and other non-cleaning systems of ventilation.

If this Society should deem it advisable to render such an opinion, we would take great pleasure in placing it before the Committee on Ventilation of Public Schools of New York City, where it will without question, be of great value, not only to New York, but to the art of ventilation in general.

Yours very truly,

CHARLES G. ARMSTRONG.

Mr. Stannard read a paper on "Heating and Ventilating the Northwestern University Buildings." It was discussed by Messrs. Hale, Whitten, Richards, Capron, and Donnelly.

Chairman Hale: If there is no further business before the

meeting we have completed our business, except the several topics of discussion, which are not actually a part of our proceedings. If there is nothing further to be discussed by any of the members or any remarks to be offered, will some one move we adjourn?

On motion the meeting adjourned.

List of members and guests present at the Semi-Annual Meeting, Detroit, Mich., July 11–13, 1912.

R. W. Alger
J. E. Anderson
A. S. Armagnac
J. P. Berry
J. R. Bolton
John Boylston
E. P. Bradley
W. R. Brewer
J. A. Bursley
E. F. Capron
O. T. Carson
F. T. Chapman
W. H. Chapman
I. B. Coe
R. T. Coe
Ralph Collamore
S. C. Cutler
J. V. Dailey
C. W. Daines
J. H. Davis
J. E. Degan
J. M. Doesburg
J. A. Donnelly
R. L. Douglass
S. O. Dugger
H. W. Ellis
S. E. Fenstermaker
W. M. Foster
H. T. Gates
J. B. Gaugh
H. B. Gombers
Joseph Graham
J. F. Hale
H. A. Hamlin
E. M. Harrigan
N. A. Henwood
G. D. Higgins
J. D. Hoffman
P. A. Hoffman
T. E. Keegan
W. J. Keep
A. W. Kelly
J. C. Kenney
W. M. Kingsbury
G. H. Kirk
B. E. La Follette
William Lees
J. F. Lewis
S. R. Lewis
C. W. Locke
E. J. Lomasney
J. I. Lyle
W. M. Mackay
W. W. Macon
W. H. Mason
E. A. May
J. J. McDonald
W. F. McDonald
J. M. McHenry
C. McSorley
Joseph Meehan
Aaron Miller
C. M. Minnick
M. E. Monash
C. F. Newport.
C. J. Peck
F. G. Phegley
A. G. Pittelkow
D. M. Quay
H. J. Rademacher
A. C. Rogers
E. W. Sanborn
J. O. Sargent
E. A. Scott
J. D. Small
E. D. Smith
L. C. Soule
J. G. Sorgen
J. M. Stannard
F. R. Still
Donald Stuart
T. C. Taylor
H. S. Van Valkenburgh
A. W. Varney
Fred Venton
C. H. Vitalius
J. W. Walker
E. E. Walton
Theodore Weinshank
A. E. Werkhoff
W. T. White
H. W. Whitten
H. L. Williams
T. Wilson
Weston Wrigley
O. A. Wurm

LADIES

Mrs. J. H. Davis
Mrs. A. W. Kelly
Mrs. William Lees
Mrs. W. W. Macon
Mrs. F. G. Phegley
Miss Phegley
Mrs. A. G. Pittelkow
Mrs. Donald Stuart
Mrs. A. W. Varney
Mrs. E. E. Walton
Mrs. Theo. Weinshank
Miss Anna Weinshank
Mrs. H. W. Whitten
Mrs. Weston Wrigley

CCXC.

HEATING IN TURKEY.

BY JOHN R. ALLEN

President of the Society.

Constantinople, May 26, 1912.

To the American Society of Heating and Ventilating Engineers—Greetings:

It is with great regret that the following paper is sent to the Society to be read, for I should much prefer to present it myself. Unfortunately, Constantinople is too far away to permit returning to the meeting, and I can only send the Society greetings and my best wishes for a successful meeting.

I wish to thank the Society for the honor that it has conferred in electing me president, and am very much disappointed that I shall not have the opportunity of taking an active part in its meetings during the coming year. The war between Italy and Turkey, and the closing of the Dardanelles, have seriously interrupted the work here, and I shall be detained much longer than was anticipated. In fact, doing work here takes at least twice as long as in most countries of Europe. The best I can do is to send a few thoughts, and as my residence is at present in Turkey, some observations in regard to business conditions here may be of interest to the Society.

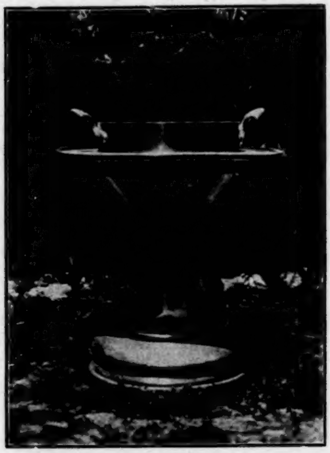
To understand the business conditions in Turkey it is necessary to have a little insight into the Turkish character. The Turk is a fatalist; everything that happens in Turkey is the will of Allah. The Turk builds a house of wood and paints it. The paint wears off, the boards begin to rot and finally fall off, but no repairs are made, because it is the will of Allah that all things should decay and pass away. This fatalistic belief of the Turkish people is seen on every side, and is a most difficult thing to contend with in business life. It is one reason why the Christians have done so much better in business than the Mohammedans. In fact, most of the business of Turkey is done by Christians, and it is a recognized condition, true everywhere throughout Turkey, that the Turk steadily becomes poorer and loses ground to the Christian. There is a very good reason for this: the Turk has always been a warrior, and business life and methods have little interest for him. In the old days he waited until his Christian neighbors acquired property and wealth and then he took it away

from them. It is to be hoped that under the new rule of the "Young Turk" pillage and massacre may be done away with. But with the new policy of Turkey, the Turk must learn entirely new business methods or eventually take a very subordinate place in the Turkish business world. It seems almost inconceivable that the Turk, with his fatalistic ideas and his lack of business training, could establish new business conditions.

On every side there is evidence of these changing conditions in Turkey. New houses are being erected in all the cities and villages. In Constantinople new office buildings are being constructed, and many new ones are being planned. These buildings are being equipped with modern appliances, and many of them are quite up to date in their equipment. The main streets of the city, formerly seldom more than 20 or 30 ft. wide, are being widened. In the residence district of Pera a boulevard has been constructed wth asphalt pavement and elaborate parking. Concessions for telephones, an electric lighting plant and electric car lines have been granted and the construction of these works is now in progress. A new bridge across the Golden Horn has been completed and is provided with street railway rails and electric lights. The present sewerage system is very inadequate, and is now being enlarged and extended. These new sewers are being made of brick and reinforced concrete, and take the place of the old sewers of rough slabs of stone. All of these improvements would have been impossible under the old régime of Abdul Hamid, but the policy of the new government is to encourage modern developments. The Turk is being rapidly educated to make use of the luxuries of modern civilization, which we consider necessities, such as telephones, electric lights, elevators, modern plumbing and central heating.

The Turkish houses are, as a rule, built without provision for any form of heating. There are no chimneys in the ordinary Turkish house, and many of the houses being built to-day are still constructed without chimneys. The forms of heating used in the ordinary Turkish house are such as do not require a chimney; the same is true of their means of cooking, which is ordinarily done over a charcoal fire. The fire is started in a pan out-doors, and when the coals are burning well, they are brought into the house and placed on a grate held by a brick or stone shelf. A separate fire is made for each cooking utensil, and, for

an elaborate meal, as many as ten or twelve separate fires are used. The American cook stove is unknown in Turkey. What a field for some enterprising American stove concern! How many times Mrs. Allen has expressed a wish for a good American cook-stove. Our present cook-stove is one made by a Levantine Italian, and embodies all the wrong principles known to stove making. With much effort and consumption of fuel it can be made to boil water, but to bake—never!



OLD TURKISH MONGOL MADE OF HAMMERED COPPER.

The heating in the Turkish houses is done with open charcoal fires. In the better houses these fires are made in elaborate mongols. These mongols are usually made of copper or brass, and are raised from the floor on a standard or on legs. They look much more like jardinière stands than like stoves. The fire is started out of doors, and when it is burning brightly is brought into the house and put into the mongol. It will burn for an hour or two without replenishing. We sometimes use one in my office, but it is a very poor substitute for a steam radiator. The poor people make a mongol by taking an oil tin, removing the top, and then running rods through the tin about 2 in. apart and 3 in. from the bottom. This forms a grate upon which a charcoal or coke fire is made. A small hole is cut in the tin below the grate to form the ash pit door and give draft to the fire. A complete heating plant can be produced in this way for an expense of not exceeding 10 cents. Most of the workmen use this system of heating for their houses and shacks. The system has one good feature: its efficiency is 100 per cent.

Grates are very little used in this country for two reasons: coal is very expensive, and the native workman has never learned how to construct a grate properly. The most popular form of heating is a stove—usually one that will burn either coal or coke. These stoves are, for the most part, what are known as air-tight

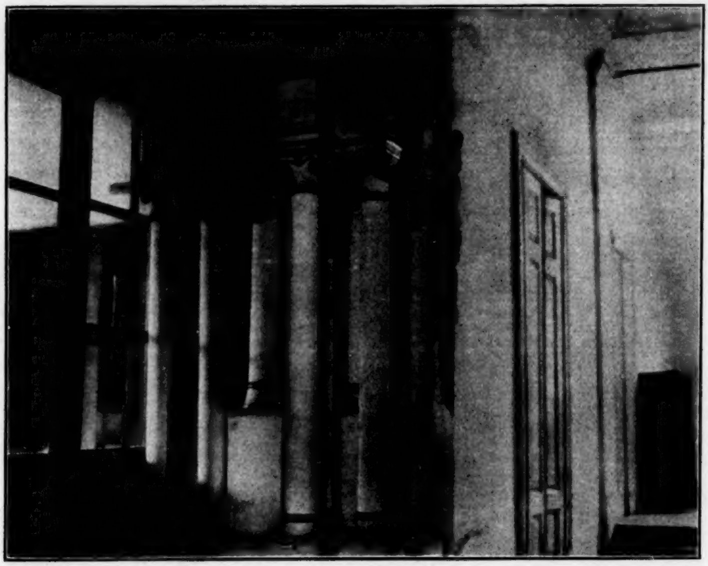
stoves and are made in Belgium. The American air-tight soft-coal stove should find a good market in Turkey. The wealthier families often use the German tile stoves. These look very well, and are often quite large, reaching almost to the ceiling. They heat up very slowly, but retain the heat for a long time. The use of them is diminishing, however, as they require too many repairs.

The most elaborate stoves are from Russia. The first time that the writer saw one of these stoves was in an old Turkish palace, which had two of these stoves in the entrance hall. At first they were thought to be some sort of a shrine at which the family worshipped, or, perhaps, erected in commemoration of some departed member of the family. On closer examination we found that the supposed shrines were hot. They consist of a central portion made of cast iron, in which the grate is located. The flames pass up through this central flue to a cast-iron chamber, which forms a manifold. From this manifold cylindrical pipes are carried down to a cast-iron base under the firebox, to which the smoke flue is attached. There are some ten or twelve small round pipes, elaborately decorated in white and gold in this case, which carry the gases from the upper portion of the stove to the base. The whole appearance of the stove is not unlike a shrine, as the upper part of the stove is covered with numerous ornamental domes and turrets. These look less like heating apparatus than anything the writer has ever seen. Occasionally one sees an American or English wood stove, but only in houses of European families.

A great many of the older buildings are now being heated by stoves, and, not having chimneys, the stove-pipes are put out through one of the windows and the pipe is carried up the side of the house, sometimes over the street. Along the Bosphorus, in many places, one may see soldiers' barracks, and even fine palaces of marble, with numbers of stove-pipes reaching out like long, black tentacles from many windows and extending above the roof. To a European they look most grotesque, and quite inconsistent with the building architecture.

In the business section of Constantinople, a number of office buildings have been built recently and these buildings have been provided with central heat. In every case I think the system is operated with hot water. Steam heat has been very little used in

Turkey. These hot-water systems have been installed by either English or German contractors. The systems, as a rule, have a very crude piping system, much more complicated than necessary, and the pipes are quite small. Fortunately, not much heat is required in Turkey, and poor operation is not so noticeable. There is one very desirable addition that is made to almost all European steam or hot-water heating plants, and that is the providing of a valve for each radiator which controls the amount of heat given



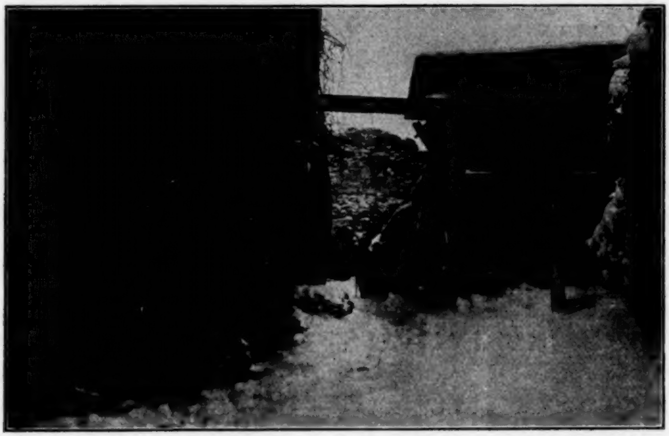
RUSSIAN STOVE TO HEAT THE HALL OF A LARGE HOUSE BELONGING TO A PASHA.

to the radiator. In the United States the use of a controlling valve by which part of the heat may be turned off the radiator is very limited, but in Europe the use of such a valve is the rule. There is a great lack of heating contractors in Constantinople. There are only two concerns that can really construct a good heating installation in this city of over a million inhabitants, and in a climate where heating is necessary from November till May.

Central heating in Turkey has been limited almost entirely to the heating of public buildings. The Turk has yet to be educated to heating his residence by central heat. There should be a large field for the hot-air heating system, but as yet this system is un-

known in Turkey. In some respects it would be most desirable for this country. It is inexpensive, can be easily installed in a wooden house (and most Turkish houses are of wood) and heat can be quickly obtained. This year we hope to install some of the first hot-air systems of heating in the new residences to be built on the Robert College grounds.

The heating of a number of buildings from a central heating plant has not yet been done in Turkey. There are, however, two plants of this kind being installed, one at Arneautkeuy in the



STOVE PIPE RUNNING ACROSS THE STREET, A COMMON SIGHT IN TURKEY.

American School for Girls, and the other which the writer is installing at Robert College. There are a number of institutions in the country which will undoubtedly be supplied in the future with central heating systems using the exhaust steam from their electric light plants. As German and English heating engineers have had very little experience in this line, the American engineers have by far the best opportunity to take up work of this kind.

The American manufacturer has done but very little to push his trade in this market. It will not be difficult for him to compete with Europe, as the prices are much higher here than in America. Freight rates from England and Germany are almost as much as those from New York. The freight rate on machinery from London to Constantinople is 25 shillings per ton, and

from New York to Constantinople 27 shillings per ton. Railroad freight rates are so high that shipping heavy freight from western Europe to Constantinople is never thought of, and shipping by rail here is looked upon in the same way as shipping by express is at home. As an American citizen, the writer should rather see American supremacy in commerce and industry than that the United States should own a piece of the North Pole, or an island in the South Sea. The business invasion of such countries as Germany, England and France is a difficult matter, as their business conditions are firmly established, but Turkey offers a free field, and by systematic effort this market could easily be persuaded to purchase American goods. America has strengthened her position in the last few years by having a more efficient and active consular service. Our consul and vice-consul in Constantinople have a thorough knowledge of the people and speak the languages. A proper co-operation of our American business men with the American consular service will do much to increase our foreign trade in countries such as Turkey.

CCXCI.

TEMPERATURE EQUIVALENTS OF WIND VELOCITIES.

BY H. W. WHITTEN.

In January, 1911, the author reported to the Society the result of observations at the group of buildings of the Harvard Medical School. The total heat expended and average temperatures and average wind velocities were recorded daily during the months of January and March, 1910. A comparison of these records showed that 1 mile of wind movement per hour required substantially the same amount of heat supply as 1 degree change in temperature. A further study of similar records, however, has shown that 1 mile movement of wind per hour does not bear a constant equivalent to 1 degree drop in temperature. There appears to be a greater proportion of loss due to wind movement as the temperature drops.

This led the author to make investigations as to the impact effect of wind of the same velocity at different temperatures. He found that there is a regular rate of increase in effective pressure as the temperature drops, although the wind velocity remains constant. This regular rate of increase of pressure is maintained only while the barometer readings are normal. A barometrical change caused changes in the impact pressure. The author was unable to determine the exact rate of this change, but was able to detect the fact of such change, the tendency being for an increase in pressure as the barometer rose and for a decrease as it fell.

He estimated, however, that, with the barometer and the wind constant, the increase in pressure is 0.4 per cent. per degree drop in temperature. He also found that the non-pressure or suction on leeward sides of buildings increased in about the same proportion. The point at which heat loss from 1 mile of wind movement per hour and temperature were equal seemed to be between 36 and 39 deg. above zero. Above this temperature,

the effect of wind became less important than the temperature changes, and below it, correspondingly more important.

For example: If, at 37 deg. plus, 1 mile of wind movement per hour is equal to 1 deg. drop in temperature, at zero, 1 mile of wind movement per hour will equal 1 deg. plus 37×0.004 or 1.148 deg. If the temperature increases to 50 deg. plus, then 1 mile of wind movement equals $1 - 13 \times 0.004 = 0.948$ deg.

Mr. Albert F. Zahm, secretary of the Aero Club of America, has made exhaustive experiments on the subject of wind pressure at varying temperatures. He states that, with velocity meters placed in the same vicinity, different readings are found to occur simultaneously in the several instruments. If, however, each air-meter is read in conjunction with a pressure meter the results become more intelligible. He further states that a change in temperature of 3 deg., or a barometer change of 8 millimeters, will alter the pressure 1 per cent. with the wind constant. He found that variations were also caused by the moisture content of the air, but that this element was so slight as to be negligible. Moisture is never over 5 per cent. of the mass of the air and rarely over 2½ per cent. The difference in weight between air and water vapor being small, this factor does not appreciably change the result.

The author has adopted as a rule for personal guidance the following: From 40 to 15 deg. plus, 1 mile of wind movement per hour is equal to 1 deg. drop in temperature; from 15 deg. plus to 20 deg. minus, 1 mile of wind movement per hour is equal to 1.15 deg. drop in temperature. This is for buildings constructed in the ordinary manner, that is, without protected windows. Applied strictly to the glass surface, the loss from wind movement may be calculated as only $^8/_7$ of the loss under usual and ordinary conditions. This not only applies to the sides having the so-called greatest exposure, but, owing to the suction or non-pressure existing on the sheltered sides, should be applied to all sides of the building.

DISCUSSION.

Mr. J. D. Small: I would like to ask on what type of buildings these observations were made, whether office or factory buildings.

Mr. J. A. Donnelly: I think this subject of impact effect of wind might be studied mathematically and shown graphically by figuring the impact of the wind as it varies with the weight of the air; that is, that a diagram might be drawn showing the increasing impact of the air as it cools in temperature and so becomes more dense and as the height of the barometer increases. As the air increases in weight, its impact should be greater upon an instrument for measuring such force.

Mr. Theodore Weinshank: Referring to the author's statement that "from 40 to 15 deg. F., 1 mile of wind movement per hour is equal to 1 deg. drop in temperature," this refers to the so-called windward, or indirect side. Will this hold also on the non-pressure, or suction, side of the building? The author states that it will, without giving any data. If this effect is true on the windward side of a building, I do not think it could be true on the suction, or non-pressure, side.

Prof. J. D. Hoffman: The author says that "the difference in weight between air and water vapor being very small, this factor does not appreciably change the result," I would like to ask his opinion in regard to that.

Mr. Whitten: In regard to the type of buildings, they are a group of educational buildings. They are quite large, and have the average number of glass openings. The buildings are constructed in the form of a U, with the open mouth of the U facing about northeast and having windows on all sides. The sides of the U are subdivided, with courts, so that there are wind pockets and there are practically all the irregular conditions that might be found in various types of buildings.

Mr. Small: It occurred to me that with a corridor, the corridor would act as a ventilator. In that case, the building being constructed as you say, it might tend to decrease the proportion of loss on the suction side. But if it were a factory building, I can see how the infiltration and outward leakage might possibly be in the same proportion.

Mr. Whitten: In regard to the suction side of buildings, this outflow was ascertained by special apparatus applied to the cracks about the windows and about the doors on the various faces of the building, an instrument that would record air movements in or out. There appeared to be a slightly greater outflow in all cases where there was an inflow. These buildings

are heated by steam radiation, supplemented by a supply of warm air delivered by fans. It has been my experience in investigating these conditions for some years that almost invariably where there is an independent air supply to the buildings from the walls or wall crevices, that the outflow, provided that the building stands in an isolated position, will be greater in volume than the inflow.

CCXCII.

THE TIME ELEMENT IN HEATING APPARATUS.

BY JAMES A. DONNELLY.

The time element of a heating apparatus as a whole may be defined as the time elapsing from the initial firing of a plant at any given outside temperature to the moment when the temperature of the building has been raised to that for which the apparatus was designed. An analysis of the subject might be divided into a consideration of the time required to heat a radiator or other part of an apparatus which has been shut off and allowed to cool (the time required to heat up the piping, radiators, etc., after the fire has been banked over night); and also a consideration of the comparative time required in bringing a steam, hot water or hot air apparatus to its maximum temperature. The time element may also be considered in the light of the cooling curve of the apparatus or the building. In all calculations of this character, the higher mathematics give exact results, but for an easy understanding of the subject approximate calculations will be considered sufficient for all practical purposes.

Calculating the time necessary to heat an individual radiator can best be done by considering one in which the maximum opening of the supply valve is supposed or intended to be just sufficient for the normal heating of the radiator at the pressure designed when the room is 70 deg. With this opening and under the given pressure, no steam is supposed to pass to the return, but only water of condensation. Assuming the average cast-iron radiator to weigh 7 lb. per square foot of surface and the specific heat of the iron being 0.13, it will take $7 \times 0.13 \times 150 = 136.5$ B. t. u. to raise the temperature of the radiator from 70 to 220 deg. If the radiator gives off 250 B. t. u. per square foot per hour when fully heated, or 4.1 B.t.u. per minute, the mean emission from the radiator per minute during the time of heating the radiator (starting at 70 deg.) will be one-half the amount, or 2.05 B. t. u. per minute. Thus, while the supply of heat to

the radiator is at the rate of 4.1 B. t. u. per minute, 2.05 B. t. u. on the average are emitted to the air, leaving the remainder, or 2.05 B. t. u., to serve for bringing the iron up to temperature.

In the instance cited it will accordingly take $136.5 \div 2.05 = 66\frac{1}{2}$ minutes to heat the radiator. In other words, if we divide the number of heat units required to heat the metal of a radiator by the supply of heat available per minute for the purpose, the quotient is the number of minutes required for the operation. The available supply per minute is the number of heat units represented in a minute's supply of steam diminished by the mean number of heat units transmitted through the outside of the radiator to the air. If we let I represent the amount of heat required to heat the radiator and R the amount of heat brought to the radiator per minute and E the mean amount emitted per minute, then the number of minutes required to bring the radiator to temperature, M, is equal to $I \div (R\text{-}E)$.

The foregoing brief analysis is rather too approximate, as the rate of heat emission is not constant for a wide range of temperature differences. For example, when the mean temperature difference between the air and the metal of the radiator is, say, 10 deg., the heat emitted, according to tables available on the subject is 0.55 B. t. u. per degree per square foot hourly, while if the difference is as much as 150 deg., the coefficient is no less than 1.64 B. t. u. per square foot per degree per hour. Accordingly, we may make a more extended analysis for the same conditions and find that, as a matter of fact, it will take hours for the radiator to get up to steam temperature, depending on how quickly the air surrounding the radiator becomes warm. Indeed, if conditions were such that the air outside the radiator remained at some low temperature, say 30 deg., the radiator would never fully come up to temperature, assuming, of course, that it is supplied with no more than the normal amount of steam it is expected to condense with the ambient air at 70 deg.

Suppose the radiator is located in a room with the air at 30 deg., and the steam is then turned on at the rate to supply the so-called normal amount, namely that equivalent to about 250 B. t. u. per square foot per hour. Then for every minute that the radiator is in operation it receives 4.1 B. t. u. Suppose that the radiator has become warmed to 50 deg., and the temperature of the air has not been measurably increased. The mean differ-

ence in temperature between the radiator and the air is 10 deg. As the transmission of heat to the air for this temperature difference is about 0.55 B. t. u. per hour for every minute that the radiator is in operation under this average temperature difference, the radiator loses to the air $(0.55 \div 60) \times 10 = 0.09$ B. t. u. The difference between the heat supplied and the heat given to the air is therefore for every minute $4.1 - 0.09 = 4.01$ B. t. u. As the radiator has in the meantime been warmed to 50 deg., this difference of heat has been stored in the radiator and is equal to $7 \times 0.13 \times 20 = 18.2$ B. t. u. As the amount of heat available for storage in the radiator is 4.01 for each minute, it is obvious that the number of minutes required to warm the radiator is $18.2 \div 4.01 = 4.54$ minutes.

In the same way we can imagine the radiator warmed from 50 to 70 deg. We can then assume that the air has by this time reached 31 deg. The mean temperature then between the radiator and the air is roughly 29.5 deg. From tables of heat transmission from radiators we can assume a value of 1.18 B. t. u. per degree per square foot per hour for the transmission, and, proceeding as before, we ascertain that the number of minutes required to warm the radiator from 50 to 70 deg. is $18.2 \div (4.1 - 29.5 \times 1.18 \div 60) = 5.17$.

By taking successive steps and allowing for a gradual increase in the surrounding air, successive values of the time interval may be calculated. For example, we may assume that by the time the radiator has reached 150 deg. in temperature the air is 35 deg., and then that each square foot of the radiator or a given square foot of the radiator is warmed to 170 deg., with an increase in air temperature to 36 deg. Here with a mean temperature difference of about 124.5 deg., and a corresponding coefficient of heat emission of 1.55 B. t. u., the number of minutes works out to be 20.7. So long as the difference in temperature between the radiator and the air is less than 150 deg., which difference is that for assumed normal operation, the radiator can continue to warm up toward steam temperature.

While extended figuring along these lines is of no importance *per se*, it goes far to show how important a factor the initial warming of a heating apparatus may be. For example, pursuing the figures but a step further, they indicate that even allowing the air to take on 4 deg. (from 36 to 40 deg., in other words)

while warming the radiator from 170 to 190 deg., the time required to accomplish this increase figures out at 70 minutes, so great is the amount of heat constantly going into the air from the radiator in relation to the total amount supplied in the same time.

To bring out the point a little more clearly, accompanying curves are presented. Curves A, B and C show the time required to warm the radiator when it is started at a temperature of 70, 50 and 30 deg., respectively, the air remaining at these tempera-

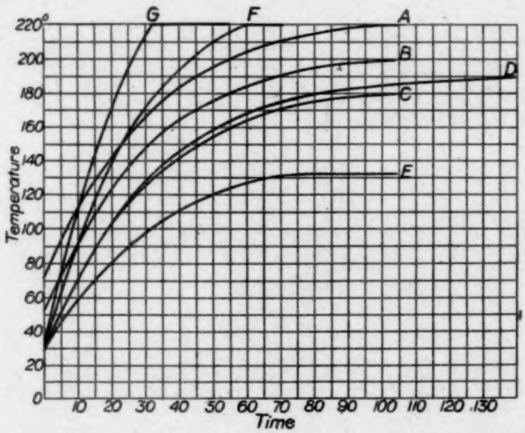


FIG. 1.—TIME IN MINUTES REQUIRED TO HEAT A COLD RADIATOR.

tures. They would indicate that instead of the radiator reaching the steam temperature in an atmosphere of 70 deg., within shortly over 60 minutes after turning on the steam, as the first rough calculation showed, it would take over 100 minutes. Curve B shows that with the air remaining at 50 deg., the temperature would not pass 200 deg. on the average, the difference between the air and the radiator being the 150 deg. mentioned. All the iron would be heated to a temperature which would correspond to an average of 150 deg. Curve C indicates in a similar way that the air remaining at 30 deg., the radiator would not pass 180 deg.

Curve D is one allowing for a gradual increase in the air temperature. In this particular case it is the curve for the heating up of a radiator starting at 30 deg., and allowing for a

gradual warming of the surrounding air. It will lie to a greater or less extent above Curve C, according to the rapidity with which the surrounding air is itself warmed. It will continue on the upward rise until, of course, the radiator assumes steam temperature. Curve E corresponds to Curves A, B, and C and is for a hot water radiator starting at 30 deg., in an atmosphere remaining at that temperature and allowing for 100 deg. between the air and the radiator temperature under normal conditions. Curve F is drawn for a steam radiator started at 30 deg.,

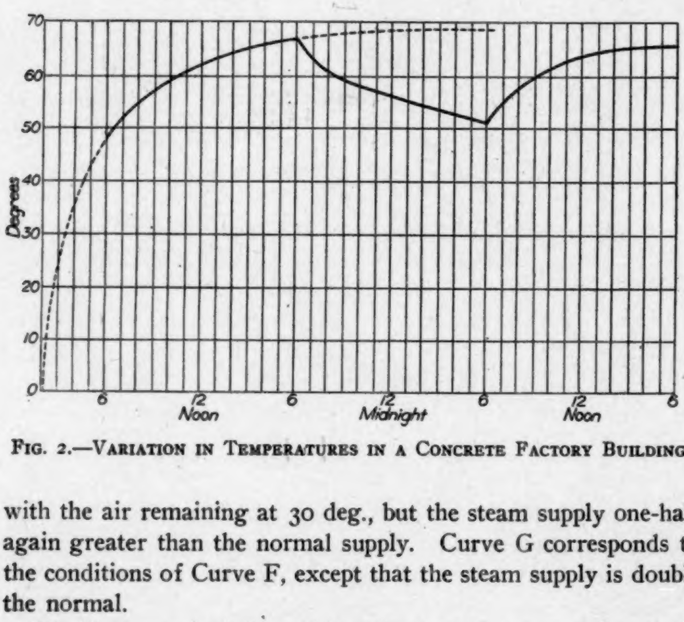


FIG. 2.—VARIATION IN TEMPERATURES IN A CONCRETE FACTORY BUILDING.

with the air remaining at 30 deg., but the steam supply one-half again greater than the normal supply. Curve G corresponds to the conditions of Curve F, except that the steam supply is double the normal.

The time required for raising the temperature of the air in a building after the apparatus has become heated has been studied somewhat by the use of recording thermometers. Fig. 2 gives the record of a recording thermometer placed on the top floor of a concrete constructed building in Brooklyn. The fires had been banked during the previous night, and had been started up so that steam reached the top floor at 6 o'clock a. m. on Thursday, January 11, 1912. The temperature of this floor rose, as indicated, during the day, until 67 deg. F. was reached at 6 o'clock p. m. The fires were then banked and the temperature dropped

to 51 deg. at 6 o'clock a. m. the following day. The temperature was then raised by the heating apparatus during this day about the same as on the previous day.

If the curve of the first day is extended, it would seem as if the temperature would have reached 69 deg. about 2 o'clock a. m. If the curve is dropped from the opposite end, the indications are that it would reach zero at the point corresponding to 2 o'clock a. m. the previous day. From this it might be deduced that if the building were at zero, it would take about 24 hours to have it reach 70 deg. As the guarantee in this building was for only 65 deg., it will be seen that the contractor's guarantee was fulfilled, though this temperature was not reached until 3 o'clock p. m. the first day and 2 o'clock p. m. the second day.

Fig. 3 is taken from the chart of a recording thermometer

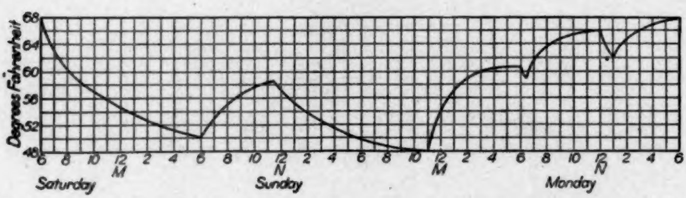


FIG. 3.—RECORD OF TEMPERATURES IN FACTORY OVER SUNDAY.

which was placed in a mill construction building February 23 to 25, 1908, during a very cold spell of weather. It illustrates very nicely what often happens over Sunday in a factory building. This building contained a great deal of machinery, as well as metal in the course of manufacture, which would probably affect to a considerable extent both its heating and cooling curves.

The chart starts at 68 deg. at 6 o'clock p. m. on Saturday, when steam was shut off the building. The rule of operation of this plant was to allow the building to drop to 50 deg. before turning on steam. This point was reached at 6 o'clock a. m. on Sunday, when live steam was turned on, heating the building to about 59 deg. at 11:30 o'clock a. m. Steam was then shut off and the building cooled down to 48 deg. at 11 o'clock p. m. Sunday, when steam was again turned on. It was kept on until 6 o'clock a. m. Monday, when it was shut off preparatory to starting the engines. During the one-half hour that it was shut off it will be seen that the temperature dropped about 2 deg. Ex-

haust steam was then put on and the temperature reached 66 deg. at 12 o'clock noon. During the noon hour, while the engines were shut down, no live steam was used, and a drop of 4 deg. is recorded. Exhaust steam being turned on again, the building reached a temperature of 68 deg. at 6 o'clock p. m. Monday.

Fig. 4 shows the heating of a drying room by fan blast apparatus, using exhaust steam at 1 lb. pressure. It will be noticed that this drying room rose from 70 to 152 deg. in 3 hr. Wet goods were then introduced, which cut down the temperature, but when the room was again closed up this temperature rose to 170 deg.

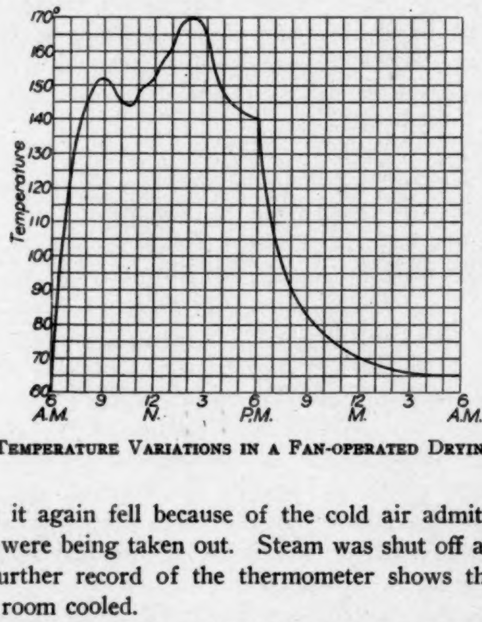


FIG. 4.—TEMPERATURE VARIATIONS IN A FAN-OPERATED DRYING ROOM.

After that it again fell because of the cold air admitted while the goods were being taken out. Steam was shut off at 6 p. m., and the further record of the thermometer shows the rate at which the room cooled.

The time element in regard to the cooling curve of buildings presents one other feature of considerable interest. The collection of a number of cooling curves from the same class of buildings would, all other things being equal, indicate the difference in the rate of air leakage. It might then be possible to specify the kind of construction which would be expected in a new building, as one which, when heated to 70 deg., would not have more than a certain specific drop in temperature in a given number of hours, when the outside temperature is at a particular point.

This would be an indication of the value of weather stripping, for example, in maintaining the temperature of a building when heat was shut off.

Perhaps the usual guarantee that apparatus shall be of sufficient capacity to maintain a temperature of 70 deg. in zero weather, in case of a building which is continuously occupied, might be modified to a guarantee that the apparatus shall be capable of raising the temperature of the building from, say, 50 to 70 deg. in 3 hr., when the outside temperature is at zero, in the case of a building which is occupied intermittently. It is doubtful if sufficient data are available at the present time to figure intelligently for such a guarantee, but it is hoped that an extended study of the time element may render such data available.

DISCUSSION.

Mr. E. A. May: The author states that with 2 lb. steam pressure in the radiator, the temperature of the iron in the radiator was 220 deg. The conduction of iron is well known and if the radiator, under these conditions, emitted 250 B.t.u. per square foot per hour, it would mean a temperature difference between the two forces of the radiator of only 0.6. It is well known, too, that the temperature of the iron in a radiator does not approximate the temperature of the steam, otherwise there would be no transmission of heat from one to the other. The outside wall of a radiator is, by actual measurement, but little higher in temperature than the surrounding air. I should like to know by what means the author obtained the temperature of the inside wall of the radiator. In most testing methods it has been a difficult matter to measure this.

Mr. Donnelly: If Mr. May has those data available, that the outside wall of a radiator is but little higher in temperature than the surrounding air, I would say that this fact has escaped me thus far.

Mr. May: The government has published a brochure on the conduction of heat through the walls of a firebox, containing reports of a series of experiments showing a very rapid drop in temperature. I do not think that with 2 lb. gauge pressure in a radiator, the temperature of the walls will be 220 deg.

Mr. Quay: If I understand the paper correctly the test

showed that the outside of the radiator was the same temperature as the inside; is that correct?

Mr. Donnelly: Substantially so.

Mr. Quay: I do not think it is possible to get that condition, especially with a cast iron radiator, until you get the temperature in the room outside the radiator up to the temperature of the steam inside the radiator. It is impossible to get that condition; and I think if the test is carried out more carefully it will be found that the outside of the radiator is nearer the temperature of the air right at the radiator than it is to the inside temperature or the temperature of the steam. It might be possible in a very thin sheet steel or some other material to have the outside temperature nearly the same as the inside, but not the temperature of the steam; but I am sure that it is impossible to get that condition inside with a cast iron radiator.

And another question, when starting up a radiator with a supply just large enough to heat the radiator under normal conditions, that is, when the room is heated to say 70 deg. and the condensation is the average, you find that the condensation is a great deal more rapid in a cold radiator and in a cold room, and the steam supply must be large enough to supply the radiator when this increased condensation from the cold radiator is taking place.

Another thing, for efficient heating it is necessary to remove water from the radiator as fast as it condenses. Coming back to the practical application of this question of how long it takes to heat a room or building, starting with it cold, we have to consider still another question of whether the air is all removed from the radiators. You cannot get it all out by pressure. Numerous tests show that the air sometimes is surrounded by steam in the radiator and while the radiator may seem to be warm all over; the facts are that there are certain places in the radiator where the air is surrounded by steam but will not mix with steam. It has to be heated by contact. It is surprising how long air will remain cold or cool in a radiator entirely surrounded by steam.

And then I think we must conclude that if this is all true it would be much better and would cost less to keep the heat on the building continuously rather than to heat it intermittently.

Mr. Donnelly: The following are the figures by which it was

determined that the entire radiator was heated up to or very close to steam temperature:

Size of radiator, 20 sq. ft. Weight, 130 lb. Temperature of steam, 215 deg. Temperature of room, 75 deg. Weight of condensation for ten minutes, 2.94 lb. Less normal condensation for one-half this time figured at 0.25 lb. per hour, that is, 0.25 multiplied by 20 (sq. ft.) divided by 12 (5 min. being one-twelfth of an hour) equals 0.42 lb., leaving 2.52 lb. as the condensation due to raising the temperature of the iron from 75 deg. to 215 deg. Therefore, 2.52 lb. condensation multiplied by 963 B. t. u. per lb. equals 2427 B. t. u. added to the iron. This divided by 130 (lb.) multiplied by 140 (deg.) rise in temperature (equal to 18,200) gives as a quotient 0.1333 as the apparent specific heat of the radiator. The steam was assumed to be commercially dry as it was taken from a separator, but may have contained a slight amount of moisture.

Perhaps if tests made in this manner with accurate instruments and careful observation were repeated by others, a more definite result could be obtained as to the exact temperature of the radiator.

CCXCIII.

OFFICE PRACTICE IN ESTIMATING HEATING AND VENTILATION.

BY JOHN D. SMALL.

In December last year the author sent out twenty-nine letters and sets of questions to members of the society on office practice in estimating heating and ventilation, and received seven full replies and two encouraging letters. More answers would doubtless have been sent had time permitted.

The questions and a summary of the answers are as follows:

1. *What rule do you use for estimating radiation?*

The majority of expressions on this question favored a formula based on the number of heat units loss through various cooling surfaces and materials and the number of heat units required to compensate for air change due to leakage and exposure. Coefficient tables for this purpose are found in a number of handbooks and the losses due to air change represent what the engineer's judgment dictates, except where fixed by law. Carpenter's and Mill's rules are largely used also.

2. *How many air changes per hour do you allow in the following classes of buildings?*

Residences.
Hotels.
Hospitals.
Office Buildings.
Store Buildings.
Theaters.
Factories (except where exhausters are used).

This factor seems to be a very indefinite one where the amount of air displaced is not fixed by law or otherwise. In buildings where no mechanical ventilation is provided, the rate

of air change would be effected by a number of causes, one of the principal causes being natural leakage, which varies with the kind of construction, the exposure, the wind velocity and the height of the building.

Under the head of construction, the kind of window frames used has a great deal to do with the rate of infiltration of air. The sides of the building exposed to prevailing winds will, of course, show a marked increase in air displacement over the protected sides. Air currents, however, between high buildings, due to deflection from one to the other, will often affect the surface which otherwise would be protected. Tests made by Mr. H. W. Whitten have demonstrated that with wind velocities below 6 miles per hour infiltration is reduced to a minimum; while with velocities as high as 30 miles per hour a very substantial effect is produced upon the rate of air change of the interior of the exposed portion of the building. Again, the leakage is relatively greater as the building increases in height due to increased wind pressure at increasing heights. From the foregoing observations it is important to use considerable judgment in arriving at the maximum allowance to compensate for losses due to this element, and in the absence of a fixed rule, the following schedule, in the author's opinion, would be a safe basis for calculating the amount of heat required under maximum conditions of air change in addition to that required to offset losses through the cooling surfaces. Allow air changes per hour for various rooms and classes of buildings as given in the table:

TABLE OF NUMBER OF AIR CHANGES TO BE USED IN HEATING CALCULATIONS.

Office Buildings—Portions above grade—1 air change per hour.
Basement, general—4 air changes per hour.
Mechanical Plant—10 air changes per hour.

Factory Buildings, which have no mechanical or natural ventilation, one change per hour. For factories where large doors from the outside are frequently opened, about four air changes per hour.

Residences—having loose windows, two changes per hour.

Churches—Four changes per hour except small rooms, which should have five to six changes per hour. These data for churches contemplate mechanical ventilation.

The majority of public buildings and many of the factories require ventilation or the fan system of heating. The usual specifications of air supplies per person are as follows:

Hospitals, ordinary—35 to 40 cu. ft. per min. Hospitals, epidemic—80 cu. ft. per min.

Hospitals—Tuberculosis	AIR CHANGE
Dejection Room	6 Min.
Toilet Rooms	6 "
Bath and Duty Rooms	8 "
Kitchen	3 "
Serving	10 "
Fumigating	10 "

Workshops—25 cu. ft. per min. per person.
Prisons—30 cu. ft. per min. per person.
Theaters—20 to 30 cu. ft. per min. per person.
Meeting Halls—20 cu. ft. per min. per person.
Schools—30 cu. ft. per min. per child and 40 cu. ft. per min. per adult.

Hotels—Follwing air changes are usual:

ROOM	AIR CHANGE
Engine	6 Min.
Kitchen	1½ "
Restaurant	6 "
Basement Toilet	5 "
Billiard	10 "
Barber Shop	8 "
Dining Room	15 "
Palm Room	12 "
Buffet	8 "
Cafe	8 "
Lobby under balcony	8 "
Main Lobby	20 "
Banquet Hall	15 "
Retiring Room	10 "
Kitchens	8 "
All others	15 "
Except Toilets	6 "

Libraries

ROOM	AIR CHANGE
Corridors	15 Min.
Basement Rooms	15 "
Reading Rooms	12 "
Inside Rooms	8 "
Corner Rooms	7 "
Toilet Rooms	5 "

Laundries—should have an air change every 4 to 6 min. Radiation on sides of buildings subjected to prevailing and cold winds should be increased 10 per cent. up to the 10th floor and 15 per cent. above.

3. *In your opinion is it more practical to heat and ventilate with hot air only or to ventilate with tempered air and provide direct radiation for heat losses through cooling surfaces?*

While a difference of opinion prevails on this subject, it seems to be desirable to provide direct radiation for use when fans are shut down. The argument is advanced that omission of direct radiation makes it impossible to heat without ventilating, as the fan must be run in order to heat. Direct radiation in addition to the fan system, one to offset the cooling effect of walls and glass and the other for ventilation only, makes a flexible system and admits of uniform regulation of temperature for various exposures perhaps better than the fan system only.

It is also true that the relation of supply and exhaust opening in a given room sometimes results in short circuiting and defeats thorough ventilation as well as requiring direct radiation to care for portions not warmed on this account. Therefore, it would appear that where possible it would not only be more practical but more satisfactory results could be guaranteed if direct combined with the blast system is installed.

4. *Do you consider it good practice to install radiation in factories only sufficient for normal winter temperatures and increase pressure to compensate for deficiency when maximum winter temperatures prevail?*

The consensus of opinion is decidedly against installing radiation in factories only sufficient for normal winter temperatures

and increasing steam pressure to compensate for deficiency when maximum winter temperatures prevail, especially where exhaust steam is used for heating, as the engines would be subject to back pressure and general efficiency reduced. The money saved on first cost of the heating system would be spent in operation later, thus resulting in poor economy on the long run. It would, therefore, appear that this method would not be considered good practice, although owners are often influenced to cut down the first cost in this way, not fully realizing the net result.

5. *Do you advocate using mains as heating surface or covering them throughout?*

The conditions and class of buildings govern largely whether the mains should be used as heating surface or should be covered. Under the head conditions, would be considered the cost of covering, the location of mains and the length of run together with the length of risers in connection with the mains. For low buildings and not excessively long runs, the mains are very often left uncovered, and without bad effects. In high buildings and in central heating systems, however, it is essential to cover mains in order to diminish the drop in steam pressure and therefore to diminish the temperature to a minimum extent at the terminals. There have been cases where the steam chilled or condensed to such an extent due to surrounding temperature that it became necessary to cover the mains. The consensus of opinion is to cover the mains, as a rule, for best results in heat distribution.

6. *To what extent do you advocate the use of vacuum devices in heating systems?*

The use of vacuum devices in heating systems is looked on with favor in the majority of cases, especially where exhaust steam is used for the following reasons: It aids circulation of the steam; tends to remove back pressure; allows small piping to be used, thus reducing cost for long runs; eliminates air valves with the attendant annoyance occasioned by adjustment, leakage, etc.

However, there are many instances where vacuum systems are of no particular advantage. On the other hand, there are cases where it is absolutely necessary to install such a system to ac-

complish circulation of the steam and the return of condensation. On the whole, installations would be benefited by the use of vacuum devices. In this connection it has been the author's observation that pipe sizes have been reduced to such an extent that instead of circulating steam at or below atmospheric pressure it was really necessary to carry from 2 to 8 lb. steam pressure to overcome the resistance in supply piping, a condition which defeats one object of a vacuum system. With a differential existing at each unit it is important to eliminate undue resistance to the flow of steam to obviate carrying excessive vacuum to balance this resistance.

7. *In your opinion, is it feasible to standardize methods of estimating heating and ventilating in different classes of building where there is no law governing the installations?*

This is a delicate question and does not permit of definite answer. The judgment of the engineer is a large factor in this connection. The author's thought in putting this question was to ascertain if, for instance, this society could consistently go on record as favoring the adoption of the method of estimating direct radiation on the heat unit basis and establish given values for various conditions and classifications and construction materials.

8. *In large open rooms, such as in stores, factories, etc., would you figure the radiation the same on all sides and then place a larger proportion on the most exposed or windward side? If so, what proportion? Or would you figure it the same on all sides and add radiation on the most exposed sides? If so, how much?*

The majority favor figuring the radiation on the same basis for all exposures and placing a larger proportion on the most exposed or windward sides, it being the idea that the heat will equalize, due to wind pressure, and eventually find its way to the opposite side of the building, whereas, if the same proportion were placed all around, the temperature on the windward side would be too low, and on the opposite side too high. To figure the radiation the same all around and then add to that on the most exposed or windward side would require more radiation

than otherwise, and would not be so effective and economical as the first method.

9. *In figuring on the basis of the heat loss through various cooling surfaces, what authority do you use for these coefficients?*

Carpenter, Wolff, Péclet, Box, values deduced from the German authorities by Kinealy and various handbooks which quote values deduced by recognized authorities are referred to for these data. These tables are very helpful in figuring the heat losses through various building materials and combinations of materials which compose the walls and roof of a structure.

10. *In estimating radiation, do you consider the type of window construction, whether loose fitting or provided with patented weather strips?*

11. *If windows are provided with weather strips, would you reduce the amount of radiation? If so, how much?*

Ordinarily it is assumed that the sash and frames are of wood, and not provided with weather strips. If concealed weather strips are used the radiation may safely be reduced from 10 to 15 per cent. While if metal sash and frames are used the radiation should be increased.

12. *In your opinion, is it feasible to heat a factory building comprised of two or more typical floors by running pipe coils around the outside walls, any given number of pipes high, regardless of the contents or floor area?*

Given a factory building, exposed on four sides and two or more typical floors, it has been held that to install pipe coils around the walls to care for cooling surfaces is sufficient to maintain proper temperature without taking into consideration cubical contents. This seems to work successfully in some cases, and in others it is found that radiation is insufficient. There is a certain percentage of a room of large dimensions which may be neglected with regard to air change, but just what proportion is yet to be satisfactorily answered. The author would like to obtain a discussion on this point particularly and wishes to thank the members who responded in the interests of the foregoing.

DISCUSSION.

Chairman Hale: I would like to ask Mr. Small if in this table, the number of air changes is a compilation of the replies received from the people to whom he wrote or whether they are the results of experiments which he has made himself.

Mr. Small: I want to give the most credit for this to Mr. Soule. There are one or two additions that I made from my own experience and practice, but the majority of these air changes are from the table which he provided and which checked largely with what my practice has been.

Mr. Soule: Those figures that I submitted in my reply to Mr. Small were obtained from the practice of various prominent and reliable architects and engineers whom I had occasion to know, and from that I have been able to get the data.

Chairman Hale: There is a subject here that I wanted to mention—the remark in reference to the tendency at times to cut down pipe sizes, which seems to be a rather dangerous thing for the average person to play with, for the reason that they may not have had a sufficient experience to determine whether certain applications are proper for small and certain applications for the larger size piping. Calculations cannot always be made theoretically to arrive at test results, as practice and experience count more than anything else in that respect.

Mr. May: The table under hotels gives the changes for kitchen 1-½ min., and kitchens 8 min. Is that a misprint, or which of the two figures is correct?

Mr. Soule: Possibly if it is 1-½ in one case and 8 in another it is explained by the fact that sometimes there are some kitchens which are termed serving rooms on different floors. The first one is no doubt the main kitchen, where the main cooking is done.

Chairman Hale: Under the subject of "Hotels" again you have "all other rooms." Does that refer to bedrooms, living rooms, libraries?

Mr. Small: Well, of course some hotels are more or less complete and others are incomplete, so that is a general term for it, in case you should ventilate other rooms than those mentioned, they would come under this head.

Mr. Quay: There is one particular place we find in practice

where a steam main uncovered is very injurious that has not been mentioned. If a main be figured just the proper size for heating the building at the desired pressure and the main is carried along in a basement close to a window, the basement becomes too warm and some one opens that window in cold weather. The cold draft blows on that steam main. The effect is likely to be that the main will not carry the required amount of steam to supply the radiation without increasing the steam pressure beyond the point of economy.

Chairman Hale: There are no doubt many places where piping could be installed without the application of pipe covering, but in general use, unless, as Mr. Small states in his paper, the owner wishes to save money, the covering should be put on to make it good engineering.

Mr. Williams: There is another point; you cannot help in a system where you put direct radiation in a room, but that some children are getting too warm. In the City of New York, you all know they put up big shields in front of the radiator, and even with them it is a very serious question whether they get rid of this objection altogether. Besides, I think that all direct radiation, to a certain extent, seriously affects the ventilation and circulation of a room. You have the direct radiation pulling the air in its direction, while the ventilating flue is pulling it its way; you therefore have two different systems in each room, one working against the other.

Now I want to reply just a minute to that part of the remarks which refers to the recirculation of air. I am one of those who believe that in time we will heat our buildings that way altogether; that we will purify our air; recirculate it and purify it again and again and send it back to the rooms of the building and thus get rid of all the dust and impurities that you now have in schools.

Mr. Soule: I would like to make an addition to my statement regarding the source of these data. They represent not only the practice of prominent architects and engineers but they are taken from the various handbooks of authorities and the handbooks of the three biggest blower companies, the American Blower Co., the B. F. Sturtevant Co., and the Buffalo Forge Co.

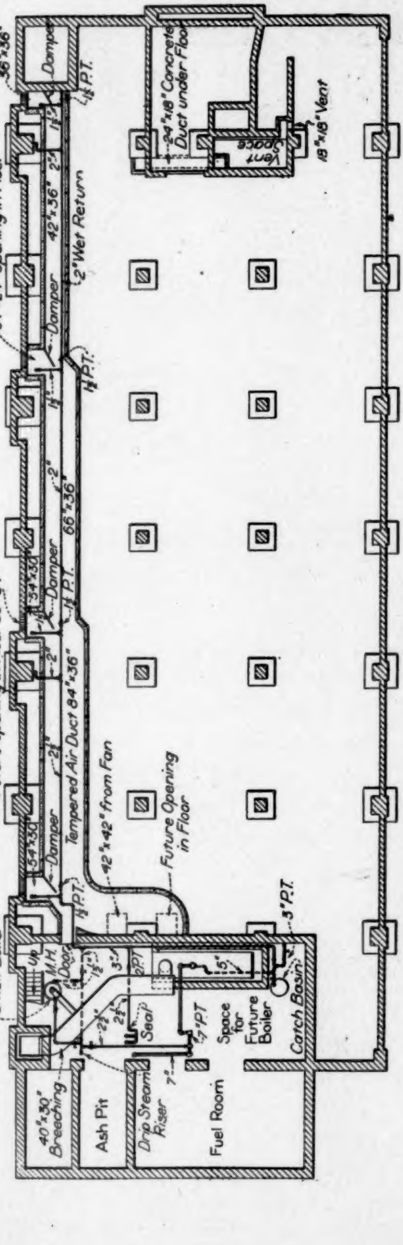
CCXCIV.

HEATING AND VENTILATION OF A MITTEN FACTORY.

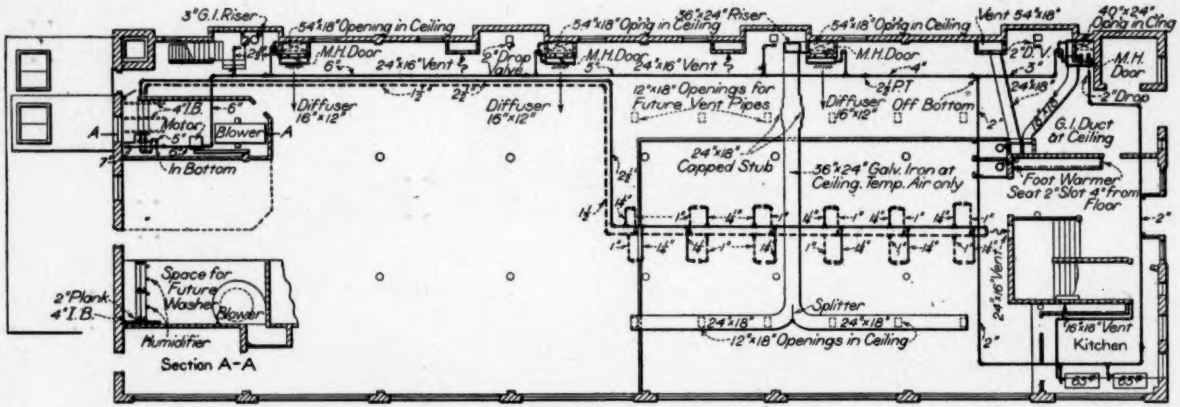
BY SAMUEL R. LEWIS.

The object of this paper is to describe the heating and ventilating arrangements of the factory of the Defiance Tick Mitten Company, Toledo, Ohio. The first floor is used for storage, packing, etc., while the second floor is occupied by about 250 operatives, nearly all women, who work at power sewing machines, pressing and finishing tables, etc. There are a number of steam-heated forms upon which the finished gloves and mittens are pressed. The desire of the owner was to provide an especially sanitary, light and attractive building, as he had learned by experience that these features had so great an influence on the attendance and efficiency of the labor that it was a good business investment as well as a function of good citizenship to provide them. The operatives are nearly all paid by piecework, and are found to be quite independent as to their attendance. By providing pleasant and healthful surroundings for the girls and women, with such equipment as individual steel lockers, a warm lunch, shower baths, rest rooms, etc., the tendency is to maintain a full force when labor is scarce, at the expense of competitors who have less attractive shops.

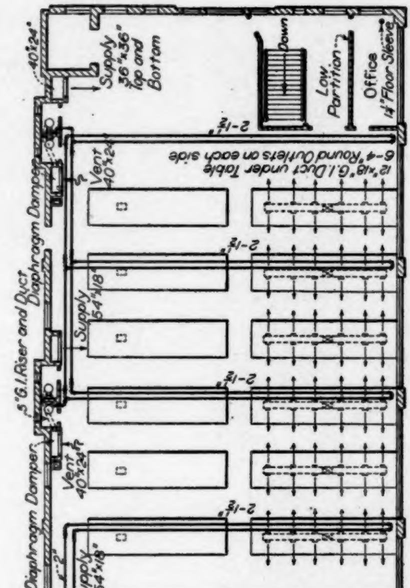
The building is of reënforced concrete construction, with brick curtain walls and a saw-tooth roof. The windows are all in steel sash. The roof is of composition, laid on matched plank, and supported on steel trusses. The building is intended as the first of a group of a similar type, surrounding a central administration building and power plant. It is one-half of a future unit, and the division of the apparatus is such that the boiler, fan, coils, etc., for the other half may be added later on. Thus, the cost of the present plant was very little in excess of what it would have been had there been no thought of future additions.



Basement Plan, Showing Tempered Air Duct Supplied by Fan on First Floor and Leading to Flues Containing Heating Surface.



BASEMENT PLAN, FAN HEATER UNIT AND ARRANGEMENT FOR DOUBLING THE CAPACITY AND THE STEAM AND AIR DISTRIBUTION, PARTICULARLY FOR THE SECOND FLOOR.



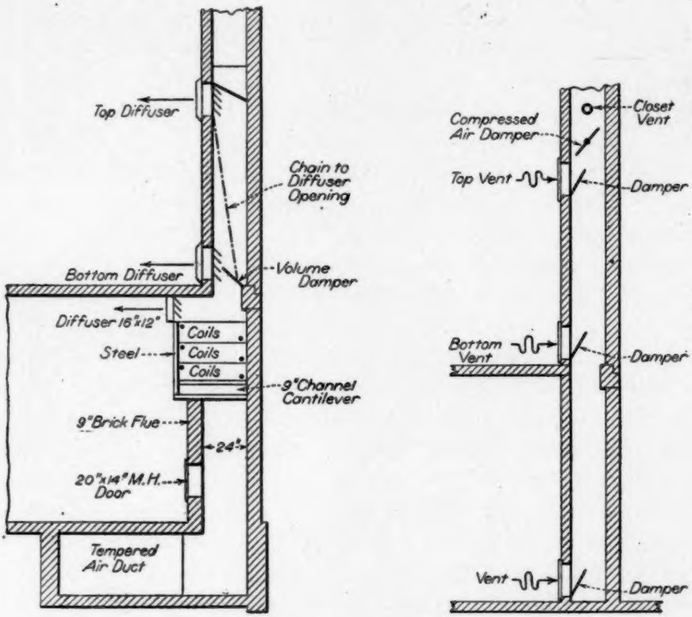
SECOND FLOOR PLAN, SHOWING AIR SUPPLY UNDERNEATH TABLES, HEATING COILS UNDER THE SECTIONS OF THE SAWTOOTH ROOF AND LOCATION OF FRESH AIR AND VENT FLUES.

The boilers are placed in a sub-basement; one has capacity for all heating, ventilating and manufacturing requirements, and the other is provided for summer use for manufacturing and water heating. The principal manufacturing demand for steam is for heating the metallic forms used in pressing the finished product.

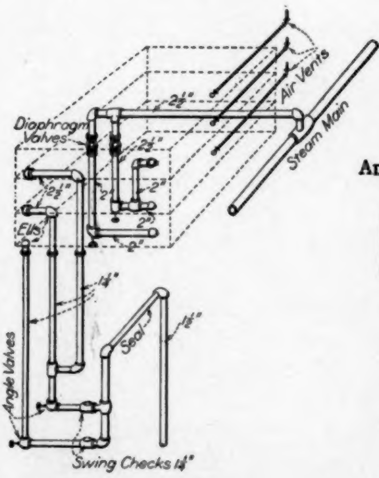
Fresh air is supplied through special steel casement sash, and is drawn through tempering coils and steam jet humidifiers to the supply fan. The steam supply to the tempering coils is controlled by a thermostat so that the tempered air is never cooler than about 60 deg., or warmer than that, unless the outside temperature is higher than 60 deg. The steam jets are controlled by a sensitive element which operates within a range of less than 5 per cent. of the point at which it is set (about 40 per cent. relative humidity). The supply fan delivers this conditioned fresh air through a concrete duct (which also serves as a return pipe trench) to the bases of the various flues. These flues have, near the ceiling of the first floor, individual heating coils, which have automatically controlled steam supply valves. The thermostats which operate these valves are of the gradual or stage operating type, and reduce or increase the amount of heated radiating surface as the temperature requirements dictate.

The various supply flues discharge some air into the first floor, but their principal function is to serve the second floor, where a minimum of 30 cu. ft. of fresh air per occupant per minute is provided. When the building is being heated, the fresh warm air is discharged at a point about 10 feet from the floor through adjustable diffusers. It passes across the skylights and is forced against the almost continuous glass surface of the opposite wall. When the building is warm, however, the fresh air is discharged at the floor line through adjustable diffusers, directly at the lines of operatives. When heating, the exhaust air leaves the room at the floor, but when cooling or merely ventilating, the exhaust air leaves the room at the ceiling. To this end, each supply flue and each vent flue has two openings, with adjustable dampers in each.

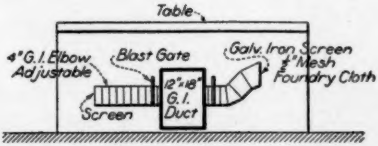
In order that the operatives at the steam-heated forms may have the maximum of comfort, a 4-in. tempered air inlet at the floor, with an adjustable universal elbow and a blast gate for regulating the volume to each person, is provided. To offset



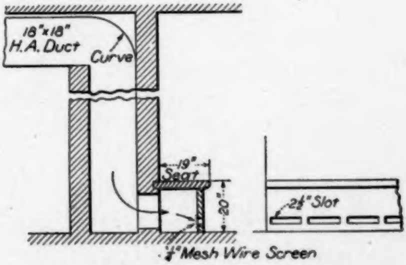
TYPICAL FRESH AIR AND VENT FLUES.



TYPICAL CONNECTIONS TO HEATING COILS.



ADJUSTABLE GALVANIZED DUCT UNDER TABLE.



AIR WARMING SEAT IN HALL.

possible cold drafts from the exposed roof or skylights, pipe coils under separate hand control are placed under each saw tooth glass area.

Many of the operatives walk some distance, and are liable to arrive at work with wet skirt bottoms and damp feet and ankles. A floor inlet would be objectionable from sanitary reasons, and so the concrete bench for drying purposes is provided and has proved quite effective. The seat is warm, about 100 deg., and through slots in its face a little above the floor, a strong blast of air at about 120 deg. maximum is delivered parallel with the floor. This air also warms the entrance hall and stairway.

The escape of air from the building when it is unoccupied may be cut off by special dampers in the outlet flues, all being operated by compressed air by one switch valve in the fan room. All toilet fixtures are individually ventilated through local vent openings in the bowls to separate vent flues.

There is no direct radiation. The plant has been in operation through the severe weather of the past winter, and has proved entirely adequate. There have been no objectionable drafts, though many operatives sit at work directly alongside the exposed glass surface opposite the supply inlets. It has been found so far that the coils in the skylights are unnecessary.

The ventilation has been excellent. It has been found economical to keep the outlets closed and to rotate the air within the building, taking in no outside air when heating prior to occupancy. There has been increased comfort and no objectionable odor when the humidifying apparatus was in use, and when the temperature was kept down to 65 deg. There was no serious complaint of overheating with the temperature at 70 deg. and the humidity at 40 per cent., relative.

The absence of direct radiators contributes greatly to the ease of cleaning, and to the comfort and fuel consumption. With this system, the loss of heat through the glass and wall surface, for instance, is less, since the inside temperature is close to 70 deg. all over, while with direct radiators it would be close to 212 deg. opposite every unit.

Langdon & Hohly, of Toledo, Ohio, were the architects of the building.

DISCUSSION.

Chairman Hale: About the center of page 374 the paper says: "The supply fan delivers this conditioned fresh air through a concrete duct." Is it customary in your practice to use concrete return trenches for ducts?

Mr. Lewis: In this case the boiler room is the only excavated basement part. The heating coils are near the ceiling of the first floor, and they did not like to run the return pipes back along the wall. This duct is 6 ft. in width and 22 ft. deep. We ran the return pipe back in that duct. It puts it where you can get at it and it is accessible and dry, due to the air around it.

Chairman Hale: There is another point here, the introduction of individual heating coils at the base of flues. Isn't that somewhat antiquated and out of use?

Mr. Lewis: I don't know. The reason that I did it was this: "If I put the coils all down at one end I would have had to blow the hot air from these coils down into the underground coil and up again, which would have been rather going against nature." I feel that the installation of heating coils, properly designed, with some little intelligent use in arranging them, is strictly modern.

Chairman Hale: The reason that question was asked was because not long ago in one of the Western States I ran across a plant where a number of suggestions had been made by different contractors, and one contractor made the same suggestion which you have here, of putting coils at the base of the flue. Six other contractors suggested mass coils, and the man that had put in the coils at the base of the flue was considered to be out of date and was thrown out. You do not look at it in the same way, evidently.

And another point in this description that you have here on page 376, about the third paragraph, the foot and dress warmers, isn't it possible to contaminate the air in the room by such a practice?

Mr. Lewis: I do not see any reason why it should be.

Chairman Hale: Bringing up all the dirt and the filth from the street on the dresses and then evaporating it and throwing that into the room, isn't it bad practice?

Mr. Lewis: You have to get these girls' feet warm.

Chairman Hale: Wouldn't it be better to extract the air from the building rather than throw it in among the operators?

Mr. Lewis: I want to make it clear that this bench is located in the front vestibule. The air that goes into that vestibule does not go into the floor of the building except just to warm the corridor.

Chairman Hale: Was the humidity you introduced there introduced because of the fact that this was a yarn mill or because you wanted to get comfort for the operatives?

Mr. Lewis: Purely a question of health and freedom from sore throat.

Mr. Whitten: I notice on page 374, about the center line of the middle paragraph, is this: "Fresh air is supplied through special steel casement sash, and is drawn through tempering coils and steam jet humidifiers to the supply fan. The steam supplied to the tempering coils is controlled by a thermostat so that the tempered air is never cooler than about 60 deg., or warmer than that, unless the outside temperature is higher than 60 deg."

Now this air, as I understand it, is cold when the steam for humidification is introduced into it; it is drawn through a tempering coil first and then through the humidifiers. That is a method we are pursuing in our committee work on schoolhouse ventilation in the testing station in Boston. The air is warmed first and then the steam is supplied to it for moistening. I would like to ask if you have any difficulty there about any lubricating oil or anything of that kind showing up in the air.

Mr. Lewis: The reason for putting the steam jets back of the tempering coils was that by measurement the air can be made to absorb very much more moisture after it has been warmed, and there is no danger of freezing. I tried a new form of spray head which proved very satisfactory. The ordinary device for putting the steam into contact with the air, used with automatically controlled humidifying installations consists of a wick-wrapped perforated pipe. The wicking gets dirty and rots and the contact between the steam and the air is not very intimate. I remembered having driven down a well once, and a well point occurred to me as a good spray device. Well points may be purchased at a very low price from supply houses, can be had in

1 in., 1½ in. or 2 in. diameters and in lengths up to about 36 in. They are made of brass pipe drilled full of small holes and covered with very fine mesh, heavy brass screens. I made up a manifold of these covering the face of the tempering coils, using six, I think, on a tempering coil 6 ft. wide and 8 ft. high. The results were satisfactory.

Mr. Whitten: Did you have several of them?

Mr. Lewis: Yes, about 2 ft. apart.

Mr. Donnelly: I would like to ask Mr. Lewis how much economy he thinks there is in this indirect radiation due to not heating up the outside walls that he speaks of in the close of the paper. About what percentage of economy does he think it would be?

Mr. Lewis: I do not think it is to be compared with direct radiation without ventilation. I do not claim that we can ventilate and heat a building as well by putting in a small amount of radiation and not ventilating. But I do know from experiments in the Chicago schools that the average amount of coal used in five buildings in which they had direct radiation and fan ventilation per thousand cubic feet of space per season was 1.11 lb. of coal per cubic foot per season, taking the average of five buildings of that sort. Then the average of five other buildings in which they had no direct radiation, using only a fan blast system, such as this is, was 0.67 lb. That was a very careful test and the results can be proven.

Mr. Donnelly: About what would be the proportion between the power required to drive the fan and the steam power required by heating apparatus?

Mr. Lewis: In this particular case the boiler is 70 h. p. and the fan is 5 h. p. We do not need 70 h. p.

Mr. Williams: I would like to ask Mr. Lewis whether he thinks it is at all times best to keep his temperature say at 60 deg.?

Mr. Lewis: I do not pretend to say. I said about 60 deg., somewhere in that neighborhood. My experience is the temperature must be such at the tempering coils, in spite of the sun and wind, and whether the day is cold or not, the room will be held at 70 deg. or whatever you want to keep it. For jobs depending on such conditions as whether the heating coils are all turned on or not, it is necessary to keep it cooler than that.

Mr. Williams: I found last winter in a building that I have examined thoroughly that it is not best in real cold weather to keep the tempering coils at 60 deg.; that in the average you will get the very best results by keeping it at 80 or 85 deg., because of the enormous cooling that is going on.

Mr. Lewis: That point is governed by the effect in the rooms. The warm air must be warm enough so that when introduced into the room it does not fall too suddenly to the floor, but the tempered air going into the room will fall to the floor.

In this little installation, the object of having the little bottom inlet registers was for use in the summer time and in the mornings. They can blow that air out and keep the upward air ventilation, which we have proved pretty thoroughly is the proper way to get rid of foul smells, introducing cold air below and forcing the hot air out at the ceiling. But that does not do when the air we are introducing is colder. Then we have to force the cold air out.

CCXCV.

HUMIDITY IN RELATION TO HEATING AND VENTILATION.

BY L. C. SOULE.*

The first record of an attempt at artificial humidification was prior to 1838. The House of Commons, London, England, was provided with an artificial humidifying device, involving 5,000 sq. ft. of moist surface, obtained by perforated water pipes, from which water issued in spraying jets from minute orifices. During the period of a very few hours 70 gal. of water were thrown into the House of Commons at one time, evidently during test.

In 1845, Mr. Walter Bernan wrote as follows: "According to the table a cubic foot of air at the freezing point can retain 2.53 grains of water only; if, therefore, it contains 1 grain only, then each cubic foot will absorb or carry off 1.53 grains of vapor from a moist surface, which may be the insensible perspiration from the surface of the body. If this air be heated to 60 deg., a cubic foot of it will carry off 5.22 grains of moisture from the skin; for it is seen from the table that air at 60 deg. can suspend 6.22 grains of water. To carry off 23 grains of insensible perspiration per minute will therefore require about 15 cubic feet of the colder air, and about 4.4 cubic feet of the warmer air. If less than this be supplied, the moisture will accumulate on the skin, and the air of the room become saturated with vapor.

"If the average temperature of the room be taken at 64 deg. with the dew point about 50 deg. or with 4.53 grains of water in each cubic foot, then about 9.25 cu. ft. of air will be required per minute for the insensible perspiration, and in addition 1 cu. ft. nearly for the excess of moisture from the lungs not carried off by 1,440 cu. in. allowed for the dilution of the carbonic acid gas; so that 10.25 cu. ft. of pure air a minute must be allowed

* Based on a report made to the Illinois Chapter, February, 1912, by L. C. Soule, J. D. Small, H. W. Ellis and W. L. Bronaugh.

to ventilate each person. But if a greater proportion of moisture is added artificially to the air, this quantity must be increased. In every case ventilation should be regulated with reference to the hygrometric condition of the warmed air."

This gentleman was a few years in advance of the present original discoverers. No doubt, between this period and recent years, quite a number of people have thought and worked on this subject, but apparently not a great amount was accomplished, otherwise years ago we would have given this matter careful consideration.

It does not appear from a survey of the authorities on record regarding humidity that they know just what is the physical effect of a deficiency of humidity or how the ill effects which are attributed to lack of humidity are really brought about. A very formidable array of authorities, together with their quotations, is given by Mr. J. I. Lyle in his paper read before the annual meeting of the Society in January.

There are probably more forms of humidifiers on the market for commercial purposes, such as cotton mills, etc., than have ever been proposed for any other service. The heating engineer will probably find that either the steam jet or spray devices, such as are used with air washers, are probably better adapted for his work than some of the devices that are proposed for commercial purposes. The growing demand for better means for dust elimination has compelled the engineer to install air washers for plants provided with mechanical ventilation. In fact, the use of air washers has grown very rapidly, and to-day it may be said that their installation is almost universal in the better class of plants.

The adaptability of the air washer, together with the increasing demand for pure air and the elimination of dust, naturally directs the engineer's attention to the air washer and appeals to him on account of its utility so that to-day there are very few high-class installations that are not provided with air washers. Coincident with the development of the washer has been the appearance of simple methods of accurate humidity regulation. Thermostatic control of humidity now is a much used feature of the modern heating and ventilating equipment. The engineer is now provided with the means by which he can control the humidity to any desired degree, and it remains for the medical

profession to determine to what extent moisture is to be introduced.

Should the requirements of the medical profession be so great that dripping and frosting windows will occur, it will require changes in our complete construction. Such experiments as have been conducted have clearly demonstrated that the present theoretical requirement of the hygienists cannot be made without injury to the building and unpleasant results in frosting and condensation of water vapor on the windows.

The air washer is a centralized humidity-producing device and the location of the controlling element is necessarily at a point where constant temperature can be provided. In order to give close control, the temperature of the spray water should be heated or else steam introduced into the washer parallel to the spray nozzles.

It is undeniable that good ventilation and high humidity are both expensive, so that the question, from an engineering standpoint, is not so much "What is the best possible condition of humidity and ventilation?" as "What is the minimum amount of ventilation and humidity consistent with good results?" Experts place the minimum per cent. of humidity in heated buildings for personal comfort at 38 per cent., which would correspond to 3 grains of water vapor per cu. ft. at the room temperature of 70 deg. and the dew point or saturation temperature of 42 deg. Moreover we find some of the most delightful so-called dry climates in which these conditions normally obtain.

It must be borne in mind that the ordinary conception of average outdoor humidity as based upon the observations of the weather bureau is erroneous, as these observations are made only at 8 o'clock in the morning and 8 o'clock at night, at which time the relative humidity is often very high. The average range of humidity throughout the working day would probably be found to lie between 35 and 65 per cent. on any clear day.

Referring again to the frosting on the windows, if condensation occurs in sufficiently large quantities to run down on the window sill, it is objectionable and the best cure is to provide double windows, as a humidity of 35 to 40 per cent. will condense and flow on a window which the wind strikes on a cold day, viz., 10 deg. above or below zero.

The cost of humidifying cannot be considered as prohibitory

or excessive. The amount of power required for running the circulating pump for the spray water is small. The greatest expense is represented by the heat necessary to procure the required evaporation in winter. One boiler horse power is required for 3,500 cu. ft. per min., to which is added 1 grain of moisture per cu. ft. Considering a condition where the outside temperature is 20 deg., with a saturation of 100 per cent. the relative humidity inside a room at 70 deg. (not artificially moistened) would be 15 per cent. To raise this humidity inside the room to 50 per cent. would require the addition of 2.8 grains of moisture per cu. ft. If this room was in a public building which was being supplied with 30,000 cu. ft. per min. of fresh air, and where it was desirable to provide proper humidity in every room, we would have to add 84,000 grains of moisture per minute or 720 lb. per hour which would require 24 h.p. In producing this humidity the evaporation would reduce the temperature of the air about 15 deg., and this temperature would have to be raised by additional coils or heating stacks.

When using air washers for humidifying purposes the dew point thermostat is located just back of the washer and controls a diaphragm valve on the steam line to the water heater, which is an ejector using live steam at any pressure above 3 lb. In case exhaust steam is used for heating, the dew point thermostat controls a three-way valve which mixes cold water with hot water from a closed heater. In the case described above there is no tempering coil used, since the air washer is furnished with hot water. When using a tempering coil the thermostat should be located in the fresh-air inlet and set to open steam valves at 35 to 40 deg. This method of controlling humidity is effective only when the air in the room is frequently changed. It is not possible to have effective humidity control when the air is changed less than every 20 min.

In order that the air leaving the washer shall be completely saturated with moisture, it is necessary for the temperature of the water to be under control and that the form of spray be special. This requires a larger delivery of water for a given volume of air handled by the washer. The pump under these conditions usually operates at 25 lb. pressure and requires 3.8 brake h.p. for an air washer of 30,000 cu. ft. per min. capacity. To get the cost of humidifying with the air washer, it would be

necessary to add to the cost of power for driving the pump the cost of evaporating the moisture. This evaporation results in a drop in the temperature.

The washer for cleaning purposes only will lower the temperature of the air passing through the washer to within 6 to 8 deg. of the temperature of the water in the spray nozzles. Under these conditions the air is not saturated when leaving the washer. The pressure on the pump and the amount of water delivered per nozzle are less. In general, a drop of 8 degrees in the temperature of the air will occur from each grain of moisture added to 1 cu. ft. of air. Another condition to be overcome in the humidifying washer as against the standard form is the tendency for the air through the washer to stratify. This requires more spray nozzles and a higher pressure.

Quite often, when taking readings of relative humidity in winter, it will be found that the absolute humidity indoors is greater than out of doors, where the air change is small or intermittent. This is due to the hygroscopic properties of the walls, furniture and furnishings, which absorb moisture when the relative humidity is high and give it off again. In those buildings provided with mechanical ventilation which is kept in constant use the rapid and continuous circulation of the air soon takes up the moisture given up in this manner. So, generally speaking, the buildings greatest in need of humidifying apparatus are those provided with the better types of ventilating plants.

CCXCVI.

BRICK DRYING.

BY H. C. RUSSELL.

Among dryers for various materials it is probable that brick dryers have more commercial importance than any other class of dryers except, perhaps, lumber dryers. It is not the purpose of this paper to discuss the relative merits or demerits of the various brick dryers made by different manufacturers, for along general lines when they are properly designed, and properly made there is little difference among them, that is, among the type of dryers we propose to discuss.

The dryers to be discussed are the so-called progressive dryers in which the brick fresh from the machine are placed, dried on the progressive principle, and after drying are removed to the kiln to be burned. The use of the waste heat from kilns cooling will also be considered. The capacity of the machine, time for drying, number and capacity of kilns, time for burning, cooling, emptying, repairing, setting, etc., must all be taken into account in the proper design of the yard.

The old-fashioned method of "hacking" the "green" brick in narrow covered sheds in the yard grew into disrepute for several reasons. Inability to control the air conditions often produced cracking in hot dry weather and in damp weather the drying was so slow as often to tax the yard for hacking space. The construction of the hacks were generally such as would not provide proper protection against wind and rain. In a properly designed yard the brick, especially through the summer when most of the brickmaking is done, can be dried almost totally by heat which would otherwise be absolutely wasted. It is also said on good authority that with certain types of kilns the burning is more uniform if the kilns are cooled by air drawn through them by the fan instead of the heat being allowed to escape in the natural way.

The first step is to investigate so far as possible the time required and the best temperature for drying the brick made from the particular clay to be used. This may be often determined by examining other plants in the neighborhood using similar clay, or lacking this facility, a few barrels of clay may be shipped to the nearest well-equipped yard, some brick made and tried in the dryer or under special drying conditions at some testing laboratory if necessary. When these two questions have been correctly settled, if one figures correctly, there is not much danger of the dryer itself being a failure.

The time required for burning depends almost entirely on the kind of clay, as does the time to be allowed for cooling, but not to so great an extent. These factors should be investigated in the beginning, as they have a bearing on the design of the yard and indirectly affect the dryer. The best method of presenting this subject is to take an example, assuming such conditions as we might find in an ordinary yard.

The data we will assume as having been found from an investigation of a proposed plant are as follows:

Rated daily output = 100,000. Time required to dry = 24 hr.

Temperature to be maintained in "hot" end of dryer = 200 deg.

Temperature to be maintained in "wet" end of dryer = 90 deg.

Assume kilns of 200,000 bricks capacity each on a schedule about as follows:

Time	for	setting per	kiln	= 2	days.
"	"	burning one	"	= 9	"
"	"	cooling per	"	= 6	"
"	"	emptying 1	"	= 4	"
"	"	repairing 1	"	= 5	"

According to this, the total time required for a cycle or rotation is 26 days. We shall, therefore, have to provide a sufficient number of kilns to take the output of the plant for this time. It is seen this would be exactly 13 kilns of 200,000 bricks' capacity each. To provide for possible mishaps, etc., we should have at least 14 kilns.

If one constructs a schedule from the table, he will note that,

allowing for all work except burning to be stopped on Sundays, there will never be more than 4 kilns cooling at one time, and unless stops occur at other times there will never be less than one. If the setting is carried on simultaneously in two kilns, allowing the setting in each kiln to start when the setting in the preceding kiln is just done, thus making the total time for setting each kiln 4 days, it will be found that the number of kilns cooling at one time will be three at nearly all times with an occasional rise to 4 as a maximum. It is not, however, the purpose of this paper to go into any detail on this phase of the subject.

The air ducts leading from the kilns to the fan and thence from the fan to the dryer are invariably constructed of brick and are underground. Good practice has fixed the size of the duct connection to each kiln at 4 to 6 sq. in. per 1,000 brick kiln capacity, the higher figure being used for the long runs. Equalize the main duct to carry the maximum number of kilns cooling at one time and carry the duct this size to the fan inlet chamber. Remember that the kilns cooling may be any combination of the various kilns. In our example with 14 kilns of 200,000 each, the duct connection to each kiln (using 5 sq. in. per 1,000) is 1,000 sq. in. = 32 × 32 in. When the next kiln is connected the main is 42 × 42 in.; when the third is connected it is 50 × 50 in.; and when the fourth and last kiln is connected it becomes 56 × 56 in., and runs this size to the fan inlet chamber.

Dampers should be arranged to cut out any kiln when it is not supplying waste heat, and at each kiln connection a mixing damper or mixing deflector should be arranged to temper the air when starting so as to avoid injury to ducts by heating them up too quickly, as would be the case if air straight from the kiln were drawn through them without tempering. A damper about 50 per cent. larger than the main duct should be provided to take air directly from outside into the fan inlet chamber, for it is necessary at nearly all times to draw in large quantities of fresh air directly from the outside to temper that drawn from the kilns. A damper should also be provided in the main waste heat duct at this point to assist in this control.

Dryers are usually constructed with brick walls and should be as nearly fireproof as possible. They are usually 100 to 120 ft.

long, the exact length depending upon the length of the brick cars to be used, and about 6 ft. high. The width depends solely upon the capacity, the length having been determined. Generally about 6 ft. 6 in. is allowed in width for each track. The end of the dryer, to which the air is admitted, is called the hot or dry end, and the other end, at which the air is removed, is called the green or wet end. It is into this wet end that the fresh brick are placed and are gradually advanced to the hot end as dry bricks are taken out and fresh bricks put in.

Each brick car holds about 450 brick, at least we will make that assumption for our purpose. The number of cars per day is $100{,}000 \div 450 = 223$. Each car is all steel, is about 7 ft. long, and weighs, unloaded, about 500 lb. A dryer, 115 ft. long, would hold 16 cars in length, and allow 3 ft. clearance. The dryer would be $223 \div 16 = 14$ tracks wide.

Each brick as delivered to the dryer weighs about 9½ lb., and when it leaves the dryer about 8 lb. (which facts should always be investigated for any particular proposition), leaving 1½ lb. water to be evaporated from each brick in the dryer, or $100{,}000 \times 1\frac{1}{2} = 150{,}000$ lb. per 24 hr. (There is an additional amount of water sometimes amounting to ¼ lb., which is driven off by "water smoking" in the kiln.)

The average temperature in the dryer is about 145 deg., and the latent heat of evaporation at this temperature is 1,035 B. t. u., requiring $150{,}000 \times 1{,}035 = 155{,}500{,}000$ B. t. u. per 24 hr. to evaporate the water.

The water evaporated must first be raised from 35 deg. to 140 deg. (the temperature of evaporation), requiring $150{,}000 \times 105 = 15{,}750{,}000$ B. t. u. per 24 hr. for this purpose.

There are 223 cars at 500 lb. each to be raised from 35 to 200 deg. (taking the specific heat of iron at 0.13), requiring $500 \times 223 \times 165 \times 0.13 = 2{,}400{,}000$ B. t. u. per 24 hr. for this purpose.

The clay must be raised from 35 to 200 deg. (taking the specific heat of clay at 0.2), requiring $800{,}000 \times 165° \times 0.2 = 26{,}400{,}000$ B. t. u. per 24 hr. for this purpose.

The radiation from the dryer may be easily figured when the construction is determined. For the purpose of this example we will assume this to be 36,000,000 per 24 hr.

Our total heat losses in B. t. u. are as follows:

	Per 24 hr.	Per hr.
To evaporate moisture	155,500,000	6,500,000
To raise water to temperature of evaporation	15,750,000	657,000
Heat absorbed by cars	2,400,000	100,000
Heat absorbed by clay	26,400,000	1,100,000
Heat lost by radiation	36,000,000	1,500,000
Total B. t. u. per hour		9,857,000

It will, in most cases, be conservative to assume outside air at 60 deg. and 60 per cent. relative humidity, but, of course, this varies in different localities. Under this condition each 1 lb. of dry air contains 472 grains of moisture. The temperature at the outlet of the dryer may be taken at 90 deg. with 70 per cent. relative humidity. Under this condition each 1 lb. of dry air contains 162 grains of moisture. The difference, 162 — 47 = 115 grains moisture, is absorbed by each pound of dry air. There are 150,000 ÷ 24 = 6,250 lb. moisture extracted per hour or 6,250 × 7,000 = 43,750,000 grains moisture per hour. This amount divided by 115 gives 383,000 lb. of dry air per hour = 6,400 lb. per minute.

The loss in temperature for this amount of air to supply the total required B. t. u. = 9,857,000 ÷ (383,000 × 0.2375) = 112 deg., which, when added to the outgoing temperature, 90 deg., gives 202 deg. However, as we wish to hold the temperature near the hot end at about 200 deg., it is evident that we could not hold this temperature very far from the air outlets with entering air at 200 deg. For this reason it is usual to add sufficient to this temperature to offset the radiation from the dryer, although this loss has already been included in the total given. This addition would amount to 1,500,000 ÷ (383,000 × 0.2375) = 16 deg., which, when added to 202 deg., gives 218 deg. as the temperature of air entering the dryer.

The loss in temperature from the fan to the dryer may be calculated for any given case, but for our purpose we will assume it at 10 deg., which, when added to 218 deg., gives 228 deg., the temperature of the air handled by the fan.

Now 6,400 lb. air per minute at 228 deg. is 112,000 cu. ft. air

per min. handled by the fan. The friction loss in the ducts, etc., will, of course, vary for different plants and for different times in the same plant. As an average, probably ¾ oz. per sq. in. would be the proper friction loss. Assume two fans each to handle 56,000 cu. ft. per min. The 8-blade fans generally used for this work run about 6,600 ft. per min. peripheral velocity, or 110 ft. per sec. We will figure the fan in accordance with a table of properties for such fans prepared by the author and found on page 235 in "Mechanical Equipment of Federal Buildings" (second revised edition), by N. S. Thompson.

In the remainder of this paper the following symbols will be used:

P. V. P. = Peripheral velocity pressure in inches water gauge.
A. V. P. = Air velocity pressure at fan inlet inches water gauge.
S. P. = Static pressure = friction loss inches water gauge.
D. P. = Dynamic pressure = *A. V. P.* + *S. P.* inches water gauge.
M. E. = Mechanical efficiency = Air H. P. ÷ Brake H. P.
K_a = Constant for blast area.
N = Revolutions per minute.
D = Diameter wheel in ft.
W = Width of periphery in feet.
C. F. M. = Cubic air per minute.
t = Temperature of air handled by the fan.
V = Air velocity in ft. per sec.
K_o = Constant for orifice.

Since the peripheral velocity was assumed to be 110 ft. per sec., the *P. V. P.* $= V^2 \div [8\frac{1}{2}(460 + t)] = 110^2 \div [8\frac{1}{2}(460 + 228)] = 2.07$ in. *S. P.* was assumed to be ¾ oz. = 1.30 in. water. *S. P.* ÷ *P. V. P.* = 1.30 ÷ 2.07 = 63 per cent. Now refer to the table on the page mentioned, and note that for this ratio the following conditions will exist: Ratio opening = 70 per cent.; *A. V. P.* ÷ *D. P.* = 21 per cent.; *A. V. P.* ÷ *P. V. P.* = 17 per cent.; *D. P.* ÷ *P. V. P.* = 80 per cent.; *M. E.* = 41 per cent.; $K_a = 3.2$; $K_o = 0.55$. The *D. P.* = 2.07 × 0.8 = 1.65 in.; the *A. V. P.* = 2.07 × 0.17 = 0.353 in.

The diameter of the wheel can be figured by the formula, *C. M. F.* $= \pi ND^2W \div K_a$. When we substitute 6600 for πDN and $W = 0.4D$ (the usual proportion) we get *C. F. M.*

$= (6600 \times 0.4\, D^2) \div 3.2 = 825\, D^2$. Therefore $D^2 = 56{,}000 \div 825 = 68$ and $D = 8.25$ ft. $= 99$ in. Use $D = 8$ ft. 6 in.

The inlet to the fan is usually $0.61\, D = 62$ in. dia. This diameter may be checked against the air velocity as ascertained from the *A. V. P.* found. The velocity,

$$V = \sqrt{A.\ V.\ P. \times 8\tfrac{1}{2}\,(460 + t)} = \sqrt{.353 \times 8\tfrac{1}{2} \times 688}$$

$= 44.7$ ft. per sec. $= 2670$ ft. per min. Area inlet $= 56{,}000 \div 2670 = 21$ sq. ft. $= 3030$ sq. in. $= 62$ in. dia. The inlet can further be checked by the formula: Area inlet sq. ft. $= (K_0 \times C.\ F.\ M.) \div (1000 \times \sqrt{D.\ P.}) = (0.55 \times 56{,}000) \div (1000 \times \sqrt{1.65}) = 23.9$ sq. ft. $= 3440$ sq. in., that is, 66 in. in diameter. This latter formula gives the area of the inlet in the wheel while the other two gave the inlet area in the case. It merely so happened that the experimental data was worked up that way.

The speed would be $N = 6600 \div \pi D = 6600 \div 8\tfrac{1}{2}\,\pi = 248$.

The horse power may be found by the formula: $B.\ H.\ P. = (5.2 \times D.\ P. \times C.\ F.\ M.) \div (33{,}000 \times M.\ E.) = (5.2 \times 1.65 \times 56{,}000) \div (33{,}000 \times 0.41) = 35$. Use a 40-hp. engine for each fan or one 80-hp. engine for both fans. Preferably use two engines.

If we should desire to use one fan instead of two the diameter of the wheel would be $102 \times \sqrt[3]{2} = 129$ in., or, say, 11 ft. The speed would be $6600 \div (11 \times \pi) = 190$ r. p. m., and the power would be about the same as for the two smaller fans.

The outlet of each of the small fans would be 58×58 in., and that of the large fan would be 76×76 in. In either case the main duct from the fan outlets may be 76×76 in.

Generally the main air duct is run across the end of the dryer and just outside of it under the tracks. A plenum chamber is built under the hot end of the dryer for about 65 ft. of its length. It slopes uniformly from the end of the dryer, where it is about 5 ft. deep, to the end near the center of the dryer where it is about 1 ft. deep. Under each track liberal size of openings provided with dampers connect the plenum chamber to the main air duct. The air is admitted to the dryer by multiple floor openings placed under the cars.

A heater should also be installed to heat the air for the dryer

when no waste heat is available or when it is insufficient in quantity. This heater should be arranged to use either live or exhaust steam in any number of sections at any time unless the main engines are to run condensing, in which case only a sufficient number of sections to condense the fan engine exhaust may be arranged for exhaust steam.

In extreme weather it is evident we cannot heat the air to 228 deg. with exhaust steam. It is usual to figure on all high pressure steam, except on the sections set apart for the fan engine exhaust, as a basis for calculations, whether the main engines are run condensing or not.

The heat required (assuming outside air at 35 deg.) $= 383{,}000 \times 193 \times 0.2375 = 17{,}500{,}000$ B. t. u. per hour. Assuming steam at 100 lb. pressure, air velocity 1200 ft. per min. and 28 pipes deep, the condensation would be $1.68 \times \sqrt{20} \times 302 = 2260$ B. t. u. per sq. ft. per hour. Then $17{,}500{,}000 \div 2260 = 7750$ sq. ft. $= 23{,}250$ lin. ft. of 1-in. pipe. The exhaust steam from the fan engines would amount to about $80 \times 40 \times 965 = 3{,}080{,}000$ B. t. u. per hour $= 17\frac{1}{2}$ per cent. of the total steam required. Since the heat transmission with exhaust steam is only about two-thirds of that with live steam at 100 lb. pressure, we should add about 9 per cent. to the total above obtained to take care of this deficiency. This would make the total heating surface 25,200 lin. ft. of 1-in. pipe. In this case it will be well to make the heater 32 pipes deep instead of 28. The maximum boiler horse power required would be $17{,}500{,}000 \div 33{,}300 = 525$.

Now let us examine the amount of waste heat available. A brick, when burned, weighs about 8 lb., and the temperature when waste heat drawing is commenced is about 2200 deg., and the drawing will usually cease when the temperature reaches about 200 deg. Taking the specific heat of the brick as 0.2, the heat available from each brick is about $8 \times 0.2 \times (2200 - 200) = 3200$ B. t. u. As shown above, the total amount of heat required to dry each brick is $17{,}500{,}000 \times 24 \div 100{,}000 = 4200$ B. t. u. This, it will be noted, is about 30 per cent. above the amount obtained from waste heat, but it is based upon the most extreme conditions with outside temperature at 35 deg., and makes liberal provision for all losses. As most of the brickmaking is done in the summer it is evident that if we can maintain

our schedule reasonably well we shall be able to do practically all our drying with heat that would otherwise be absolutely wasted.

For instance, under the conditions of the example the heat required is to raise the air from 35 to 228 equal to 193 deg. When the outside temperature is 80 deg. the rise in temperature is $228 - 80 = 148$ deg., and the heat required will be $148 \div 193 = 77$ per cent. of 4200, or 3300 B. t. u. for each brick. In addition to this, all heat losses with the exception of that required to evaporate the moisture will be reduced from 25 to 50 per cent., which means that the entering air need not be heated to so high a temperature. When all these points are considered it leaves us ample waste heat for practically all brickmaking weather or until the temperature gets down to 45 or 50 deg.

Of course many things are going to happen to upset our schedule of operation, but good management can minimize the amount of steam used for the dryer. Sometimes the discharge flues from the dryer are connected together and run to an exhaust fan to draw the used air from the dryer. These ducts usually run crosswise the dryer at the green end under the tracks with openings in the floor above.

A fan operating under a friction loss of ¼ to ½ oz. may be used for this purpose, for it is evident that its resistance will consist mainly of the friction in the exhaust ducts themselves; as it is scarcely possible, nor is it desirable, to carry much of a vacuum on the dryer as would result if we attempted to assist the main plenum fan to any great extent by this exhaust fan. Its sole object is to insure positive removal of the used air and to keep it moving in the right direction through the dryer. It is really more of a refinement than a necessity. Should such a fan be used it would be conservative to deduct about ⅛ oz., certainly not more than ¼ oz. from the friction load on the plenum fan. This figure about represents the resistance in the dryer proper.

Mention may be made of a new system of brickmaking devised by Mr. Alex. Scott, of Knoxville, Tenn., first put into operation by him in his own yards. This system eliminates the dryer as we have been discussing it. The brick are taken directly from the machine to the kiln and are subjected to as high a temperature as the clay and consistency will stand without so-called kiln marking. The setters then proceed to the next kiln,

the kiln just left being temporarily closed, and the waste heat turned on. The setters thus proceed through a series of kilns, returning to the first kiln when the brick have dried sufficiently to stand another tier of fresh brick, etc. The off-bearing is done by belt conveyors, and in a minute or two after a brick has left the machine it is stowed away in the kiln, not to be touched again until it has been burned and ready for market.

However, there are going to be a great many more dryers built of the type the author has been discussing, as they are cheap to install, simple in operation, and if properly designed and installed are certain to give good results. The dryers are not covered by any patents. Almost every part of it even to the fan casing can be built out of the owner's own product, that is, brick. In view of the immense saving by the use of waste heat, it is difficult to believe, but is nevertheless true, that there are many brick dryers in operation just like the one we have worked out, but minus the waste heat feature.

The drying of tile is practically the same proposition as that of brick. Tiles dry more quickly than brick, the drying time depending to some extent on thickness. The ordinary fireproofing tile being porous dries very quickly. Of course the schedule for setting, burning, cooling, etc., is much different from brick, and each case should be investigated individually.

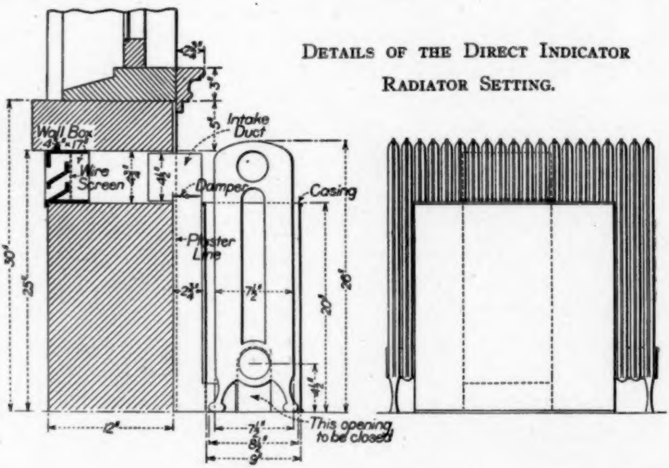
In closing I wish to emphasize careful investigation of the schedule upon which it is proposed to operate the plant, the time required for drying and the best temperatures to be maintained. These last two items as well as the time for burning will depend largely upon the kind of clay used.

CCXCVII.

VENTILATION OF A DISPENSARY BUILDING.

BY A. M. FELDMAN.

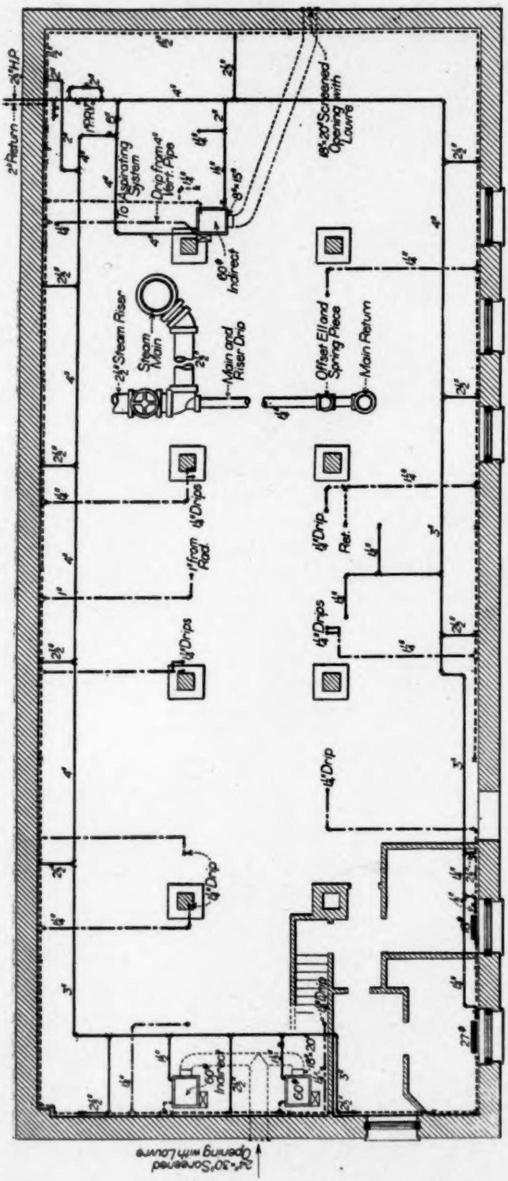
The subject of this paper is the ventilation of a new dispensary building attached to the Lebanon Hospital, New York City. Only one story and basement have been built, but provision has been made for five more stories. The first story



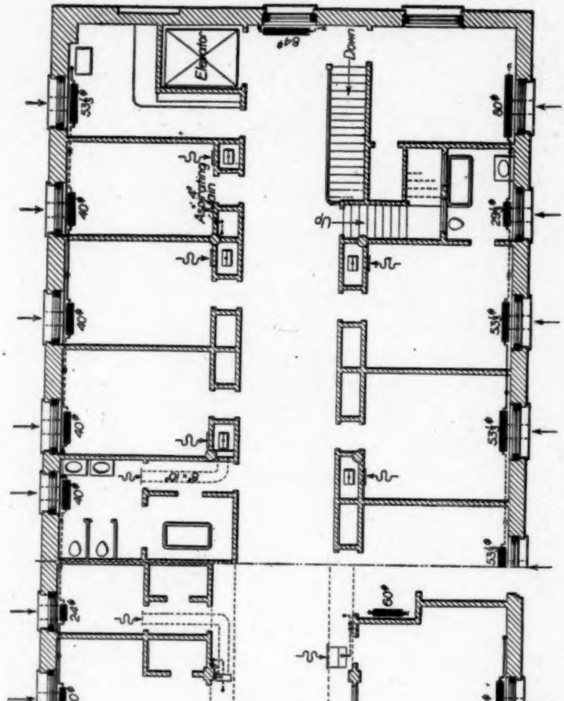
DETAILS OF THE DIRECT INDICATOR RADIATOR SETTING.

contains a main corridor running the full length of the building, with various clinical rooms on both sides. The corridor is intended to serve as a waiting room for patients, and the number of people congregating there at one time is therefore considerable. The author has accordingly concentrated his efforts on the ventilation of the corridor.

The scheme, as will be seen from the accompanying plan, is to exhaust the air from the corridor. For the admission of fresh air all the radiators in the clinical rooms are arranged as direct-indirect radiators, having fresh-air inlets through openings in



BASEMENT PLAN SHOWING INDIRECT RADIATORS AND THE STEAM PIPING SYSTEM.



HALF PLAN OF TYPICAL FUTURE UPPER STORY.

HALF PLAN OF GROUND FLOOR.

walls under the windows, with special galvanized iron casings over the radiators arranged so that they can be lifted to get at the radiators for cleaning. Only a few sections of each radiator are enclosed. To prevent cold air by-passing the radiator, the two sections of the radiator next to the ends of the casing are made with solid legs.

Doors are provided with louvers in the bottom panel. Thus the exhausting effect of the system in the corridor is to induce the air flow through the lower panels of the doors from the rooms which are supplied with tempered air by means of the direct-indirect radiators.

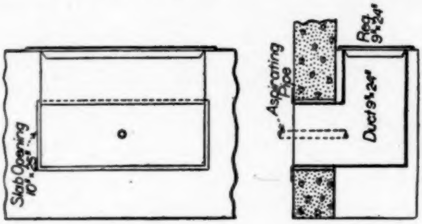
To compensate for the heat losses from the end windows of the corridor and to provide an additional supply of fresh air, indirect stacks are provided in the basement. These discharge air through large registers at both ends of the corridor. The ducts and registers are proportioned so that the air is heated not much above 70 deg. F.

Exhaust register boxes under the ceiling of the corridor pierce the concrete ceiling and discharge into a tightly constructed roof space where two 2½-in. steam mains and a 130 sq. ft. circular radiator are provided to furnish heat for aspirating purposes. Tees are provided on the pipes for extending aspirating risers through the future vertical ventilating flues required when the upper stories are built. A typical upper story floor is shown to illustrate the idea.

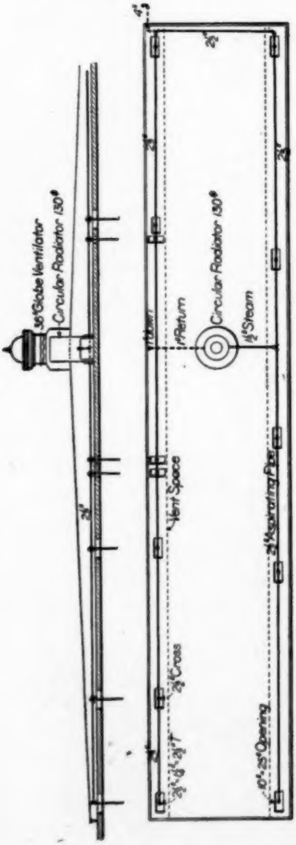
To make the system fool-proof, no dampers were installed in the registers of the exhaust or on the indirects. But to prevent any unnecessary escape of heat after the dispensary closes in the afternoon, one main damper was installed in the ventilator on the roof, operated by means of a chain from the corridor. The damper is made unbalanced so that it will always be kept open unless the chain is pulled down. The system has been in operation the past winter, and has proved a success. The air in all the rooms and main corridor has been described as always sweet. Another feature of the installation is that open windows in any of the rooms give an increased influx of fresh air without drafts with perfect circulation, as the exhaust pulls the air into the corridor.

The heating system has also some novel features. It is a two-pipe installation with a check on the return ends and no air

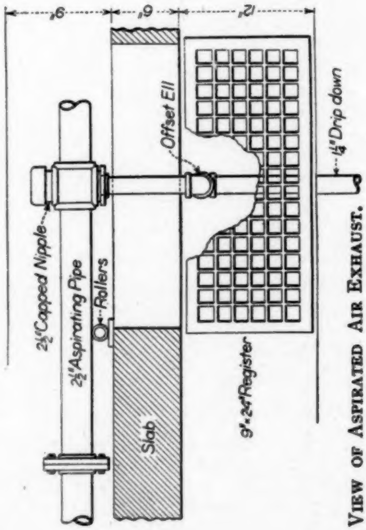
valves on the radiators, but an air valve is provided at the foot of each return riser in the basement. The steam circulation has proved to be perfect with complete air removal and without the nuisance of odors from air valves in the rooms.



DETAIL OF VENT FLUE AT CEILING OF GROUND FLOOR.



ROOF PLAN AND ELEVATION SHOWING SYSTEM OF ASPIRATING PIPES AND METHOD OF DISPOSING OF THE VITIATED AIR.



TYPICAL ELEVATION AND FRONT VIEW OF ASPIRATED AIR EXHAUST.

High-pressure steam is supplied from the boiler room and reduced at the entrance into the dispensary building. As the latter is located on a lower level than the boiler room the condensation from the heating system is gathered into a non-return trap, which discharges into a return trap. The latter lifts the water to a return tank located in the boiler house and the water is then pumped back to boiler.

DISCUSSION.

Mr. Donnelly: I am much pleased to see that Mr. Feldman speaks of this method of using check valves on the returns of the radiators and doing away with air valves. I hardly agree with him that it is very novel, because even when I started doing it six or seven years ago I found several other people were doing it before that.

Mr. Lewis: I am much interested in the claim that this direct-indirect scheme ventilates satisfactorily in this building, because I have seen many installations of that kind but I never have up to this time found any one except some one who was very strongly prejudiced who would admit or claim that the direct-indirect radiator could be depended upon with varying outside conditions to deliver proper ventilation. The experience has been that when the wind blows strongly on the windward side the air goes off more rapidly than the radiator can warm it on the leeward side. It had never been proven satisfactory in school-house work. We put in ordinary ventilating systems and blew the air through several sections of heater, and are able to control the temperature either by bypassing around the heater or cutting off part of it. With this scheme we have to go around and open each window; we have no means of changing the amount of radiation, no means of changing the amount of air admitted for ventilation purposes. I think it is a thing we want to be very careful about permitting in such a system.

Professor Hoffman: I would like to hear a discussion in regard to the cost of operating a ventilating system when you are putting good B.t.u. into the vitiated air just before leaving the building, as against doing the same work by the fan.

Mr. Davis: I notice that he has a radiator of 130 sq. ft. and has aspirating coils for ten small ventilating ducts. I believe a

small fan would do that work much cheaper than running that radiator all the time.

Chairman Hale: There is little doubt that that is true, but this paper does not go into the cost of operation at all. It simply enters into the question of whether they are getting the air pulled into that direct-indirect radiator and back into the corridor; that is all he aims at in the paper.

Professor Hoffman: I believe that his conclusions are correct, although I think we should also consider at the same time the cost of operating such a system, which is more economical than the other.

Mr. Lewis: Those of us who have ever installed warm air furnaces have recognized the fact that when the cold air duct is brought along the ceiling and drops to the floor, so as to permit it to rise up through the furnace, and the down flue which carries the air to the floor is located close to the furnace, we have trouble, due to the radiant heat from the furnace warming the fresh air downflues; thus setting up by this warming effect, a draft opposed to the fresh air current. We have learned that this scheme will not work. I notice in the paper a drawing which indicates that the fresh air is taken in near the top of the radiator and is dropped down a galvanized iron pipe almost touching the radiator, to the floor, where it turns and rises through the radiator. In my judgment this fresh air will not fall down the flue, because the flue is warm and the current will tend to go the other way.

CCXCVIII.

REMOVAL OF REFUSE AND WASTE BY FANS AND BLOWERS.

BY F. R. STILL.

The removal of waste material from machines in industrial plants by means of fans or blowers has been in general use for over 70 years. It is the most efficient and satisfactory method known; yet even now the minimum velocity or volume of air required to convey substances of varying specific volumes and densities is not known to any definite extent. With this lack of fundamental data, it is impossible to do more than give a general insight into the methods which have been successfully employed for years, to point out the opportunities for improvement and to lay before you such information as will likely be of most benefit in the practical application of such systems.

The application of exhaust fans to the handling of refuse probably dates back to soon after the invention of wood-working machinery. In the early days it was necessary to do considerable experimenting to determine the correct sizes of pipes to attach to machines of the varying types and capacities. Naturally little was known about the proper design and proportion of hoods, so considerable confusion existed for years as to the proper pipe sizes. But in due course of time a standard size of pipe was generally adopted for a given duty on a machine of a certain type and capacity, and these sizes have become almost universal.

The way these sizes were arrived at was very crude. In those days (and even by some at the present time) it was generally supposed that the pressure pushed the stuff along. Nobody thought it was the velocity, and even if they had thought of it, they had no known method of measuring the velocity as an anemometer would be quickly destroyed at such high velocities. The Pitot tube for measuring velocity was not generally un-

derstood, and, in fact, it is only within the last five years that it has been developed to an extent that makes it an accurate or dependable instrument of measurement.

Hence experimenters would put up a system of pipes, add the areas of the branches together to determine the size of fan inlet and then try the fan at varying speeds, try different shapes and proportions of the hoods, etc., until the system seemed to work all right. Probably the very next job would fail to work because the piping system was more extensive or the outlet from the shaving vault was too small, thus causing undue back pressure or some other of the many things which can happen around such plants. The first thing always resorted to was to "speed up the fan." If it worked, it was "a fine job." If, however, that did not prove effective, then the remote sections of the main pipe were taken down, the larger pipe moved along and supplanted by still larger pipe near the fan, a larger fan installed and larger branches to those machines which did not seem to have enough "draw" to them. After several similar experiences by the different builders of such equipment, they all gradually arrived at one standard size of branch pipe for a certain duty and these sizes have been quite closely adhered to down to the present time.

About the time the general form of hoods and pipe sizes had been standardized, considerable stir was created by inventors of "dust arrestors" or "dust separators" or "dust collectors," as they are variously known by different makers. These were used to trade on for many years, most extravagant claims being made for some of them and the prospective purchaser was often in a perfect maze of claims, guarantees, contradictions and threats. This, by the way, has not entirely subsided yet, though less attention is paid to it now.

Later a new angle to the business was introduced by means of the euphonious words, "low speed and low power fans." The methods pursued in the introduction of this device were almost identical with those used to push the various makes of dust separators years before, and it is safe to prophesy about the same finish eventually. Suffice it to say here that nothing can be accomplished by such fans that cannot be accomplished by any standard type of exhaust fan with even less power when properly applied than the former requires. This name has proven a

good thing to trade on and is now being pushed to the limit, but the people will eventually learn there is nothing in it.

So much for the history of refuse-handling systems, which, it is clearly evident, have been made up of cut and try methods from the beginning. The question naturally arises, why has not this business been placed on a more scientific footing long since? The answer is this:

A large part of the business has been in the hands of small concerns generally known as blow pipe makers, many of whom are chiefly tinsmiths. They have not the engineering talent, capital nor initiative to take up the work of experimentation and investigation. As for the fan manufacturers, most of them have been too busy experimenting and developing larger and more profitable fields of usefulness to devote any time to it.

A manufacturer is usually kept busy with three important things, each in themselves carrying hundreds of lesser duties, all important to the success of the business. The three main things are: 1. Getting the business. 2. Producing the goods. 3. Collecting the money. If he can sell all he can make, then he is not so apt to spend much time on experimental investigation with a view to rendering greater economy to the purchaser, unless he also sees a portion of it coming his way. That, in a few words, has been the situation with most of the manufacturers, and none of them, but one, is known to have made any effort to reduce the problems of waste removal by fans to a scientific basis, which work has not yet progressed far enough to make available any reliable data.

What causes greatest surprise is the fact that so little attention has been paid to this problem by our universities and professional experimentalists. They have spent generations experimenting on centrifugal pumps, steam turbines, steam boilers, heating and ventilating plants and various other lines of useful and economic apparatus for industrial and domestic use, and are still doing it, yet it is safe to say that none of them play a more important part in the safety of industries, the safety to human life, the economic production of manufactured goods, the economy of power and a general all-around usefulness in the industrial arts than the application of fans and blowers to the removal of refuse and waste materials.

Go through any average wood-working plant and it will be

found that from one-quarter to three-quarters of the total power generated is consumed in driving the exhaust fans for removing refuse. Great care will be exercised in buying economical motive power; the machine which has the greatest capacity per unit of power will be purchased; careful study will be given to the arrangement of the machines to reduce the labor to the minimum; the relative steam economy of the drying and heating plant will be questioned and considered; but when it comes to the refuse and waste collecting system, almost anything that will satisfy the underwriters and factory inspectors is regarded good enough.

Last summer a student in one of our larger universities spent his vacation in the office of a blower manufacturer. Before returning to finish his senior year he asked what would be a good subject to take up for his thesis. It was suggested that he set up an experimental plant and investigate the conveying of various substances by fans and blowers. This is undoubtedly the first time a thorough and systematic research into this all-important subject has been attempted, outside of the fold of those who make and sell the equipment.

It is to be hoped this start will lead to a wider investigation, as it is certain that if one-tenth of the time is spent upon it that has been spent on other things which have less promise of economic results, a great good will have been accomplished in almost all lines of manufacture. There is hardly an industrial plant but has one or more fans thus employed requiring from 25 hp. up to, frequently, several hundred horse power to drive them. It is all the more important that the work be taken up by our universities at this time, as most of the fan manufacturers have given up contracting for the installation of such plants and are less likely than heretofore to do much investigating. Further, as time goes on, there will be all the more need for it, due to a general conservation of resources, which simply means greater economy and higher efficiency.

These investigations and experiments should first determine what velocity is required to move different substances of varying weights and bulk. Then should be determined what proportionate volume of air is required to move in a unit of time a specific volume of different substances having varying weights and bulk. Air pressure is only a measure of velocity and resistance, beyond

which it has nothing to do with the moving of material, as many suppose.

The relative area of a substance has a great deal to do with the ease with which it can be moved by air. For instance, a comparatively low velocity will move a cubic foot of powdered coal which will pass through a 100-mesh wire screen. It will take double the velocity to move a cubic foot of coal which will pass through a 25-mesh screen. But a centrifugal fan cannot produce high enough velocity to move a cubic foot of coal in a solid block.

The same is true of many other substances; take for instance shavings and dust from planing-mill machinery. Twenty feet per second will move the lighter dust; 40 ft. will move the shavings; 50 ft. will move the sawdust, but there are knots, blocks, etc., which also have to be taken care of, and these sometimes require 60 ft. or more per second. Hence the velocity has to be selected which will take care of the largest and heaviest pieces likely to enter the system.

From this it will readily be seen how essential it is for economical operation to know what is the lowest velocity required to move a given substance, as the frictional loss multiplies directly as the square of, and the power to drive the fan directly as the cube of the velocity. For example: if only 40 ft. per second is necessary and 80 ft. is provided and at the lower velocity it requires 25 hp., it would require 200 hp. at the higher speed. This is not an absurd comparison, as many are the plants where just such a comparative waste of power is taking place.

Frequently the velocity as predetermined may be correct, but the volume of air for the volume of material to be handled in a given unit of time may be insufficient. In other words, the ducts are too small. Hence the fan has to be speeded up to create a higher velocity in order to move the requisite volume of air. This has exactly the same effect on the power as would the velocity if it had been figured too high at first. An example of this latter character came under observation about a year ago, in one of the largest mills in the South. Six very large double exhaust fans were installed, driven by direct-connected electric motors. The planing mill machines are all high speed, having three or four times the surfacing speed of the older types; hence there is proportionately a greater volume of refuse to handle.

The pipes attached to the hoods on the machines, being about the standard size, failed to take care of the refuse properly. The owners, having lost confidence in the contractor who installed the plant, sent in the plans with a request that they be advised as to the best course to pursue to put the plant in a condition which would be satisfactory to them.

A careful analysis of the situation showed it would require 438 hp. additional to do the work with the existing plant by speeding it up; whereas, by revising the plant on a larger scale, proportionate to the work to be done, it would require only 156 hp. more than they already had. Hence the saving would be 282 hp. by changing the plant over. At the conservative figure of $40 per horse power per annum, this would indicate a saving of $11,280, which, at 5 per cent., would represent the interest on an investment of $225,000. The owners of this plant have spent thousands of dollars experimenting on processes to utilize the waste from this mill for making various by-products, some of which have great value; hence they are more conservative about the consumption of refuse for fuel than are many others in a similar line of work.

To lay out an exhaust fan system for a wood-working plant, it is necessary to have a plan of the shop showing the location of each machine, the position of all line shafts and counter shafting, with direction of rotation indicated, the location of the boiler room, shaving vault and the available space for locating the dust separator. With this in hand, a list of the different machines should be made up, with the number of heads, length of knives, speed of feed of each, also the diameter of all saws and whether rip or cut-off saws. The number and position of all floor sweeps must also be predetermined.

Next one should map out the general scheme for the piping system, being guided by the following considerations in the order in which they are given:

1. The most convenient place to pipe the fan.
2. The most convenient place to drive the fan.
3. The most convenient place to give the most direct line of discharge to the final receptacle.

Next in order is to determine the sizes of the branch pipes to each machine, which can be done by the aid of Table I, as this

gives the standard diameters to attach to the hoods enclosing the knives and saws of ordinary machines.

TABLE I.

SIZES OF PIPES FOR PLANING MILL MACHINERY

UPPER CYLINDER. Length of Knives.	Diameter of Pipe.	LOWER CYLINDER. Length of Knives.	Diameter of Pipe.
5 inches.	4 inches.	5 inches.	4 inches.
10 "	5 "	10 "	5 "
14 "	6 "	14 "	5 "
24 "	7 "	24 "	6 "
30 "	7 "	30 "	7 "

	Diameter of pipe, in.		Diameter of pipe, in.
Matcher heads, each	5	Mortiser, floor spout	6
Sash & Cabinet Shaper, each head	4	Floor sweep-up	6
Door Tenoner	5	Rip-saw and re-saws	
Sash Tenoner	4	10 to 16 in. diam	4
Door and sash sticker, each head	4	18 to 24 in. diam	5
Blind slat sticker	4	42 to 60 in. diam	6
Blind rail router	4	Cut-off and grooving saws	
Panel raiser, each head	4	10 to 16 in. diam	4
Sand Drum, 24 in. long	4	18 to 24 in. diam	5
Sand Drum, 30 in. long	5	Band saws, small	3

Molders, Buzz Planers, Pony Planers, Diagonal Planers, Jointers and all other machines having knives or saws of dimensions given will require pipes of their respective diameters. Timber planers require 25 per cent. larger pipes than ordinary planers. High speed planers and matchers require about 50 per cent. more area than is indicated in above table.

On the plan mark the sizes of the various branches; then add these areas together whenever two or more pipes join and find the resulting diameter of the main. Continue this process until every branch is taken care of back to the fan, which finally determines the minimum diameter of the fan inlet.

If the fan selected is a size or two larger than the sum of the areas would indicate, it will do the work when running at a very much slower speed, and will require less power. For example, supposing the plant requires a 12-in. main, which with the branches and separator offers a resistance of, say, 4¾-in. water gauge. If a fan having a 12-in. inlet should be attached it would have to run at about 1,865 r.p.m., requiring 5⅞ hp.; whereas, if a fan having an 18-in. inlet were attached to produce the same velocity, it would only have to run at 1,040 r.p.m., requiring 5¼ hp. Thus the speed would be reduced 44 per cent. and the power reduced more than 10 per cent.

Having determined the size of the fan the next in order is to determine the size of the dust separator. The purpose of a separator is to remove the shavings and dust from the air blast, delivering the former into some convenient receptacle or onto the grates beneath the boiler, allowing the air to escape freely with little or no pressure or resistance into the atmosphere.

All the separators on the market, save one make, employ centrifugal force to accomplish the separation, the one exception

depending upon centripetal action. Every maker of separators sets up great claims for his particular device and some do work better than others, but, more often than not, the real difference in the results obtained, if there is any, is due to differences in engineering. Table II gives the principal dimensions of one of the standard makes of cone bottom separator. Any other good separator of this type will not be very much different in its proportions.

TABLE II.

PROPORTIONS OF DUST SEPARATORS.

OPENINGS				DIMENSIONS.			
No. and Diam. of Inlet.	Size of Inlet, in.	Diameter Air Outlet, in.	Diameter Dust Outlet, in.	Outside Diameter Cylinder, in.	Height Cylinder, in.	Length Cone, in.	Approximate weight, lb.
5	2½x9	8½	3	29½	14	26½	70
6	3x10½	10	4	35½	15½	32½	100
7	3½x13½	13	6	41½	18½	37½	140
8	4½x16	15	6	47½	21	43½	175
9	5x18	17	6	53½	23	50	245
10	5½x21	20	10	59½	26	56	315
12	6½x24	23½	10	65½	29	61½	395
13	7x27	26	10	71½	32	67½	490
14	8x30	28	10	77½	35	72½	575
16	8½x32	31	10	83½	38	77½	715
17	9x35	33	10	89½	41	82½	875
18	9x40	36	10	93½	46	85½	930
20	10x41	39	10	97½	47	89	1,000
22	10½x43	41	11	101½	49	93	1,095
23	11x45	44	11	105½	51	97	1,455
24	11x48	46	12	109½	54	99½	1,600
25	11x51	49	12	113½	57	103½	1,700
26	11½x54	52	12	117½	60	109½	1,855
28	12x57	55	12	121½	63	111½	2,035
30	12x60	58	12	125½	66	115½	2,155
32	12½x63	61	13	129½	69	118½	2,250
34	13x66	64	13	133½	72	122½	2,420
36	13½x69	67	13	137½	75	126½	2,555
38	14x72	70	14	141½	78	129½	2,745
40	14½x75	73	14	145½	81	133½	2,900
42	15x78	76	14	149½	84	137½	3,065
44	15½x81	79	14	153½	87	141½	3,235
46	16x84	82	14	157½	90	145½	3,395

The above recommendations apply to shavings, but not to light buffing dust, etc., for which the separators must be selected to suit operating conditions.

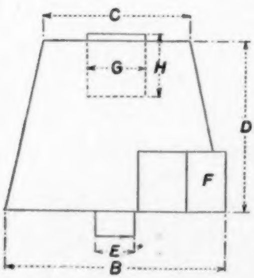


Table III gives the dimensions of another type known as a flat bottom separator, patented and owned by a Grand Rapids concern. It works well, has the advantages of being only about two-thirds the height of the other types, and is, comparatively, very easy to erect.

The centripetal type of separator referred to is made by a concern in Minneapolis. The dimensions of it do not vary to any great extent from the dimensions in Table II. The

discharge pipe from the fan connects into the central opening in the top, where the air usually escapes from most separators.

TABLE III.

PROPORTIONS OF STANDARD VERRELL COLLECTORS.

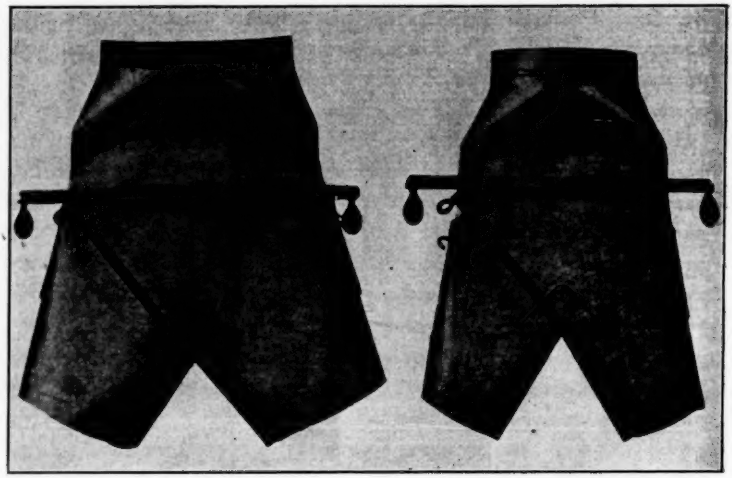
No.	Diam. Pipe from Fan.	Area Of Dust Inlet.	B.	C.	D.	E.	F.	G.	H.	Wgt. lb.
000	6	28								
00	7	38	32	26	37	7	6x7	10	12	70
0	8	50								
1	10	78	42	38	48	12	10x12	14	14	180
2	12	113	46	37	48	12	10x12	17	14	240
3	14	154	54	42	60	16	10x14	17	16	471
4	16	201	60	45	72	16	14x16	22	26	490
5	18	254	66	54	72	16	16x20	25	26	500
6	20	314	72	58½	76½	16	14x24½	27½	26	530
7	22	380	84	65¼	96	16	16x25	32	27	682
8	24	452	87	67¾	96	16	18x26	34	27	889
9	26	531	96	78	96	16	18x32	46	27	1,137
10	28	616	102	84	96	16	18x37½	40	27	1,250
11	30	707	111			16				1,500
12	32	804	114	90	120	16	22x41½	46	27	1,800
13	34	908	117	97	120	16	23x44	48	27	2,000
14	36	1,018	129	105½	120	16	24x45½	50	27	2,050
15	38	1,134	132¾	111	120	16	26x44¾	53	27	2,150
16	40	1,257								
17	42	1,385								

A good separator should not set up a resistance to the flow of air, which is in excess of the velocity head due to the flow. In other words, if the air velocity is 60 ft. per second in the discharge pipe, the separator should not offer a resistance that will increase the discharge pressure more than 0.81 in. water gauge. All makes of separators are regularly built either right or left hand.

The proper form, proportion and construction of the hoods are the most difficult to deal with on paper, of any part of an exhaust fan system.

To make a thoroughly good and efficient hood is an art. It requires the best skill of an experienced tinsmith. Of course most anything can be made to work after a fashion, but to construct a hood that does a clean job and does not require an excessive velocity or volume of air is something known to but few mechanics, very few of whom are outside the employ of concerns making a specialty of such work.

Hoods are never carried in stock by anybody, there being such a variety of makes and sizes of machines as to preclude the possibility of making a standard to fit one make of machine that will fit any other make. A governing principle for the design of hoods is to so shape them that the refuse from the knives or



EQUALIZING OR DISTRIBUTION DAMPERS UNDERNEATH SEPARATOR FOR THROWING SHAVINGS AND DUST EITHER INTO SHAVINGS VAULT OR TO GRATES BENEATH THE BOILERS.

saws is thrown directly to a point where it will be caught by the highest velocity of the air.

The hood over the upper knives on a surfacer has a mouth at the bottom several times the area of the pipe; consequently it has very little lifting power at the mouth. Immediately above the apron around the knives, the hood is drawn in from all four sides so as to reduce the area to about equal the pipe area; it is also drawn back at a considerable angle in the direction the shavings fly from the knives. Thus the shavings fly at once into the contracted area where the velocity is the highest and, being once set in motion, it is easy to keep them moving.

The hood to the bottom knives is not much more than a shallow hopper with a narrow slit at the bottom leading into a horizontal pipe. The end of the pipe is usually left open to prevent clogging up, as otherwise if the shavings should bridge over the opening in the bottom of the hopper, it would shut off all circulation and the pipe would then become dead until cleaned out. The hoods to the side heads are sometimes very complex in form, but the same principles are employed in their design as for the upper hoods.

Where the branch pipes attach to the main, they should enter

at an angle of not more than 45 deg., and 30 deg. or less is better. Never attach a branch at right angles to the main. Two branches should never enter the main directly opposite one another; also avoid the use of Y-branches, as the two currents in conflict retard the flow, sometimes causing the pipes to clog.

Elbows should have a radius in the throat twice the diameter of the pipe. For example, a 6-in. pipe should have a radius of 12 in. in the throat. There is no advantage in making the radius more than twice the diameter.

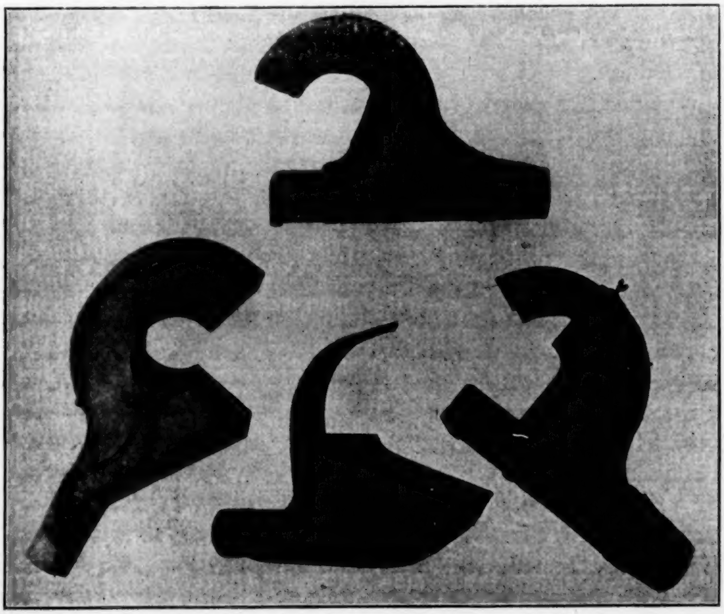
A right-angle elbow in a 6-in. pipe offers as much resistance as a straight pipe of the same diameter 44 ft. long.

With a radius of half the diameter, it is equal to a straight pipe 15 ft. long.

With a radius of one diameter, it is equal to a straight pipe 5½ ft. long.

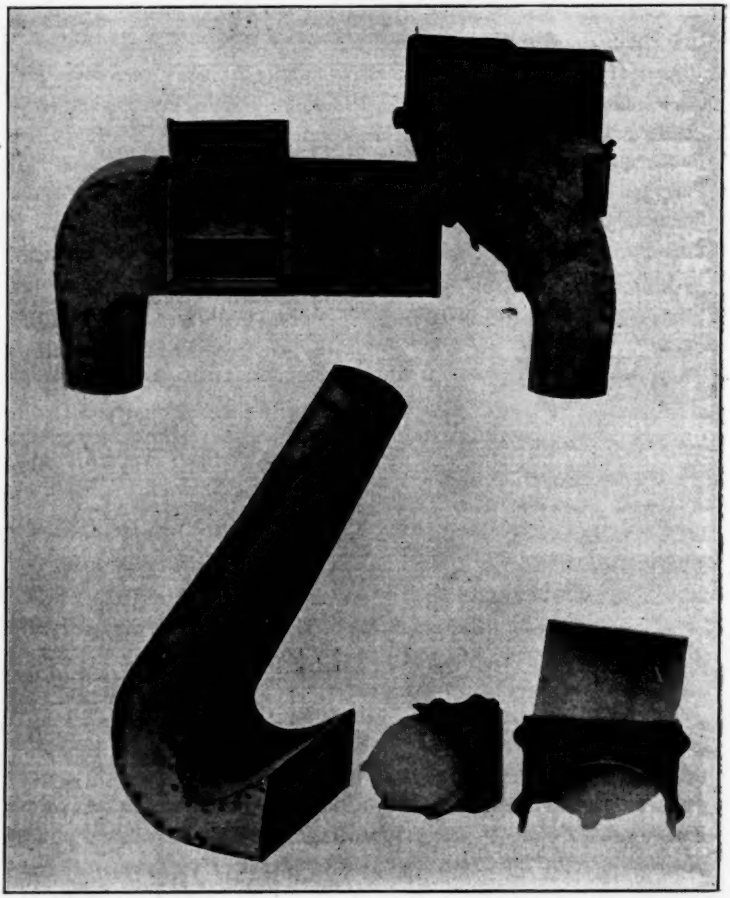
With a radius of two diameters, it is equal to a straight pipe 2¼ ft. long.

By making the radius more than twice, the resistance begins



DIFFERENT TYPES OF BUFFING HOODS FOR GRINDING WHEELS.

to increase again until at six diameters it is equal to a straight pipe 3 ft. long. This is due to the greater distance the air is under compression on one side of the pipe while making the turn.



STYLE OF HOOD FOR BAND SAW, SWING CUT-OFF SAW AND SHAPER AND ALSO SPECIAL BLAST GATES.

Friction of the air traveling through the pipes is another and very essential point for consideration, and it must be determined in order to know the minimum speed at which the fan can be run. Careful experiments have shown that a length of round pipe from 62 to 72 times its diameter will produce friction equivalent

to the velocity head, the shorter length applying to small pipes, because of the relatively greater resistance the roughness of the surface presents per unit of volume. In actual practice, it is customary to allow about 40 diameters, to compensate for branch tees, reducers, dents, etc. The refuse carried along by the air also increases the resistance somewhat.

Rectangular pipes can be compared with round pipes by multiplying the area of the square pipe by four and dividing by the perimeter of the square pipe; the result is the corresponding diameter of a round pipe for the same velocity. Or, to put this in the form of an equation

$$D = 4\,W\,H \div 2\,(W + H)$$

In which W is the width of duct; H is the height; D is the diameter of a corresponding round pipe.

The friction for varying diameters of round pipes is inversely proportional to their diameters, at a given velocity.

The friction of rectangular pipes at the same velocity varies inversely as the square root of their respective areas.

The friction of any pipe is directly proportional to its length.

As an example, take a 12-in. diameter pipe conveying air at 3,600 ft. per minute velocity at 72 deg. F., barometer 30 in., humidity 50 per cent. A velocity of 4,000 ft. per minute is equivalent to 1 in. pressure. Hence, for 3,600 ft., the pressure would be $\left(\frac{3600}{4000}\right)^2 = 0.81$ in. water gauge.

As 40 diameters offers friction equal to the velocity pressure, then $\frac{40 \times 12}{12} = 40$ ft. of length corresponds to 0.81 in. friction. As the friction is directly proportional to the length, then for 100 ft. the friction would be $100 \times 0.81 \div 40 = 2.025$ in.

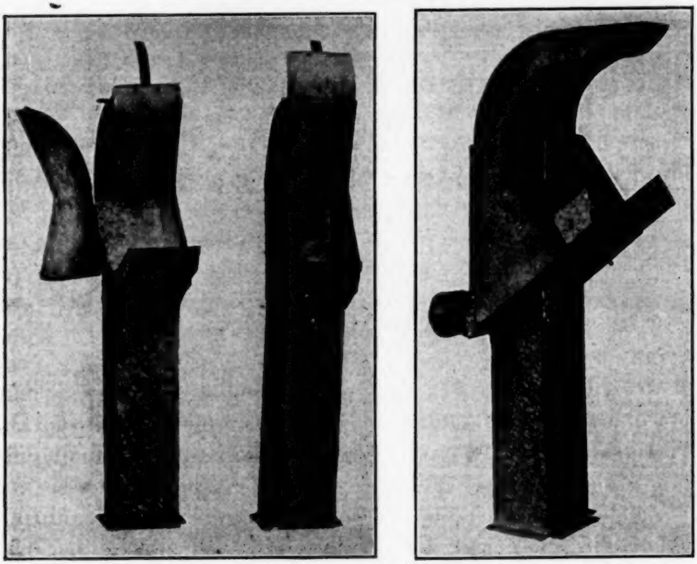
Supposing we have 100 ft. of 12×12 in. pipe. A round pipe offering equivalent friction at 3,600 ft. velocity per minute would be $\frac{4 \times 12 \times 12}{2 \times (12 + 12)} = 12$ in. in diameter.

The round pipe would, however, deliver 2,830 cu. ft. per min., whereas the square pipe delivers 3,600 cu. ft. per min.

If the friction of a 12-in. pipe is 2 in., then the friction of a 14-in. pipe would be $2 \times \frac{12}{14} = 1.715$ in.

If the friction of a rectangular pipe having one square foot area is 2 in., then the friction of a similar pipe having 2 sq. ft. area would be $2 \times \frac{1}{2} = 1$-in. friction.

In the application of fans to the removal of smoke, fumes, fine dust, obnoxious gases, etc., great care has to be exercised in so designing the hoods that they will not interfere with the process, that they will not be in the way of the mechanics, and



Special Hoods for Emery Grinding Wheels.

still be capable of catching the floating material before it gets into the room. Most failures in such installations are due to the pipes being too small.

For example, supposing a hood of conical form is 3 ft. in diameter at the mouth with a 7-in. pipe attached at the top. With a velocity of 4,000 ft. per min. in the 7-in. pipe, the velocity is only 151 ft. at the mouth, or less, about 2.5 ft. per second.

A very efficient though somewhat expensive hood of this type is to put one hood inside the other, leaving about $\frac{3}{8}$ in. space between all around the bottom, and then run a nozzle from the apex of the inner cone up into the pipe which is attached to the outer cone. This nozzle should be about half the area of the

pipe. With such a hood anything that rises up into it cannot escape around the rim even if it is not drawn off by the central connection.

A common rough rule for determining the diameter of pipe for round conical hoods is to make the bell-mouth 1 ft. larger in diameter than the apparatus it is to cover and increase this diameter 1 ft. for every 2 ft. elevation above 2 ft.; then to make the pipe one-sixth the final diameter of the mouth as thus determined. For instance, a kettle 2.5 ft. in diameter, having the bottom of the hood 2 ft. above it, would have a hood 3.5 ft. in diameter or 42 in.; the pipe would be one-sixth of this or 7 in. diameter.

Hoods to grinding and buffing lathes have to be designed to suit the character of the work done on them. A hood suited to one class of work on a given type and size of lathe may be wholly unsuited to some other class of work on exactly the same lathe. For instance, the grinding of some things can be better done on the top of the wheel, while others are more easily ground in the middle or below the center of the wheel. Like everything else, this comparatively simple thing, when viewed as a complete installation, presents its complexities and problems for solution, and it requires the same "good old horse sense," "hard knocks," experience and observation that any other engineering problem does. A discussion of the fan problem as a part of this subject has been purposely avoided, as it would take more space and time of itself than has been devoted to the rest of the subject. If one wants to know what a fan will do under certain conditions, "Ask the man who makes them."

DISCUSSION.

Mr. Weinshank: I am sorry that the author of the paper has omitted one vital point, namely, the relation of the fan used for removing all refuse to that of the heating system.

In large plants where there are large machines from which the refuse must be removed the exhaust fan has a great effect on the heating system.

I had an experience several years ago in a large mill in Northern Wisconsin where I used the blower system for heating. Knowing the effect on the heating system we required of the

owners a list of the machines which would be installed in the factory. We took into consideration the amount of air removed by the shaving fan and designed our heating apparatus accordingly. However, after the first season the owner decided to put in an additional number of wood working machines, thus increasing their original capacity about 100 per cent. The next winter we were called by the owners to find the cause of their factory not heating properly.

After explaining the reason, the owners could not see why the shaving fans would have any effect on the heating system. After demonstrating the cause of the failure, they increased the heating apparatus so as to overcome this loss and there was no more trouble.

Mr. Still, who has had experience in both the removal of the refuse and blower system of heating, could give us very valuable information if he would point out the relation between the two systems if used in the same plant.

Mr. Still: In reply to the question Mr. Weinshank raises, like himself I have had trouble in the same way when combining heating problems with refuse handling problems; I remember one instance in Kentucky where they had an excessive amount of machinery in proportion to the size and the cubical space of the building. But those fans handled just about the same volume as the heating plant did; they had a line of pipe running down overhead with branches pointing out horizontally as customarily done in buildings of that type; we simply extended these branches down so they came within about two feet of the floor, to get under the stratum which was level with the bottom of the hoods. The men previously complained of being cold up to their waists. They were warm enough above their waists but cold below. By piping the air down into the lower stratum, it overcame that complaint. I have not seen a case where the exhaust fan handled more air than was put in by the blower system, but I have seen factories which have been lowered ten or more degrees when heated by direct radiation, by introducing an exhaust system without increasing the radiation.

Mr. Whitten: It appears here that a given horse-power is more effective to produce suction than to produce pressure. I would like to know if Mr. Still has made any observations on that subject?

Mr. Still: It is impossible to remove the waste from most machines by a pressure system. It can be handled by an exhaust system much easier. There are some cases where it might be possible to attach an air blast as, for instance, on an emery wheel, to blow the emery dust into the hood, but then you have to put in an exhaust system to carry it away. You could not put in a blast system which would carry the refuse to the point of discharge very well.

As to the effect on an exhaust fan or any other kind of fan, whether it is intended to move air by exhausting or blowing, it does not make any difference, the effect on the fan and the power required is the same, although the mechanical efficiency will not show the same. You cannot get the same maximum mechanical efficiency to show from measurements taken on the exhaust side that you can on the discharge side, but the horsepower is the same. It is one of the peculiar things we have never been able to find a satisfactory reason for. It is, undoubtedly, due to some effect produced by the efflux of air into the inlet which the measuring instruments do not take into account.

Professor Hoffman: I think this is a splendid paper and one that is very timely. The engineers of the country have been spending their time largely in perfecting and improving the apparatus, the prime mover, and have neglected the outgoing system. We have been very careful to look for each per cent of efficiency in the engine but have winked at the outgoing losses. Like the man who buys a high priced engine and throws away his exhaust steam. Here we take the other end of the proposition and I think it is a splendid idea.

I would like to refer to the expression on page 409, just below the table, "On the plan mark the sizes of the various branches; then add these areas together whenever two or more pipes join and find the resulting diameter of the main," and inquire of Mr. Still if that represents his practice in laying out the mains system? Is this worked out from the standpoint of areas and velocity or does friction enter into it?

Mr. Still: Velocity only.

Professor Hoffman: Then the friction has not been taken into consideration?

Mr. Still: The areas have been added together to determine

the size of the main, and then as other branches are added in their areas are added to the last to increase it again and the velocity is the thing we have in the exhaust fan system, regardless of volume, and the friction of the entire system determines the total pressure.

Chairman Hale: I remember a case some years ago in one of the plants with which I was connected, where the apparatus was designed for direct radiation with no thought of putting in exhausters at the time the original plans were laid out. After the apparatus was started up we received a complaint that they could heat one of the buildings of the group very successfully during the noon hour, but the rest of the time it was almost impossible to get results. And when we went there, discovered that they had put in a number of shaving exhausters and the air was being drawn out so rapidly it was impossible to heat with the amount of radiation we had. We were compelled to increase it at that time, I think, about one hundred per cent in order to get results.

Mr. Soule: Just to give an idea of the amount of extra radiation required to warm the air taken out by exhaust systems, I had occasion recently to figure on a plant designed for direct radiation heating with pipe coils to take care of the transmission through the walls and roof. The exhaust fans were exhausting 85,000 cu. ft. of air per minute and it was necessary to provide 4,000 sq. ft. of blast coil surface to warm the incoming air. That figured at 1½ lb. condensation per square foot per hour would be equivalent to about 200 h. p. in addition to that required for the losses due to wall and glass.

Mr. James H. Davis: I remember two cases, one in South Bend and the other in St. Johns, Canada, where exhausters were used and where the additional amount of radiation on the floors that had exhausters was 30 per cent greater than it was on the other floors, and that was only put in after a number of trials were made to find out just what was needed, and they used almost exactly 30 per cent more than on other floors.

Chairman Hale: That was on the Singer Manufacturing Co. plant?

Mr. Davis: Yes, sir.

CCXCIX.

METHODS OF AUTOMATIC HUMIDITY CONTROL FOR AIR WASHERS.

BY J. I. LYLE.

While but few engineers, experts in hygiene, or even doctors, agree upon a standard of desirable humidity, still they are practically a unit in agreeing that some means of artificial humidification is necessary for heated buildings during the very dry weather of our northern winters. Each has some reason for believing a certain percentage of humidity is more desirable than any other or he is still investigating or awaiting data and information to assist him in making a decision. Having become convinced that a relative humidity within certain limits is necessary, or at least desirable, the best and easiest methods of procuring the regulation of the humidity becomes a subject of interest.

The desirability of breathing clean air, free from dust and impurities, is well known and in this country at least the heating and ventilating engineer who does not advocate the use of air washers is indeed rarely met. As the washing of air in practically all cases affects its humidity, it is most desirable to control this effect and at the same time provide a very simple arrangement for artificially producing the humidity desired.

There have been so many misstatements or misleading statements made about the automatic regulation of humidity that in addition to describing a method that has been proved accurate and dependable, a scientific, although possibiy somewhat academic, analysis should be given of the various methods which have been proposed. In the analysis use is made of a psychometric chart prepared by Mr. Willis H. Carrier. This, at the first sight, is somewhat tedious to decipher, but gives a very clear, graphic demonstration of the results.

The system of humidity regulation to which attention is par-

ticularly directed depends in principle upon the control of the dew point or saturation temperature leaving the air washer. Saturation is produced by heating the spray water. This water supplies the latent heat of evaporation, and, in addition, raises the temperature of the incoming air to the desired dew point; that is, to the temperature necessary to hold the required amount of moisture. The water temperature is varied as is necessary to maintain a constant dew point under variable conditions of the entering air.

The variation in the amount of work to be done is quite large. To illustrate: Supposing the requirement to be 60 per cent. relative humidity at 70 deg., F., which is the equivalent of 4.8 grains per cubic foot, or a dew point of 55 deg. Then on a zero day, with ¼ gr. of water vapor per cubic foot in the entering air, the work per 1,000 cu. ft. of air is

$1{,}000 \times 55 \div 56 = 982$ B. t. u. sensible heat to raise the air from zero to 55 deg.

$1{,}000 \times (4.8 - 0.25) \times 1{,}080 \div 7{,}000 = 700$ B. t. u. heat of evaporation.

Total heat required $= 1{,}682$ B. t. u.

In a washer using 3 gal. of water per 1,000 cu. ft. of air the necessary drop in the water temperature is $1{,}682 \div (3 \times 8.33 \times 1) = 67\frac{1}{2}$ deg. This is about the maximum requirement. Again, on a humid day of autumn or spring no heating of the water is required, since no additional moisture is needed. If a tempering coil is used in front of the washer, of course the washer is relieved of a part of the work necessary in supplying the sensible heat. In the first case of the example just referred to, with the tempering coil heating the air, say to 50 deg., the amount of heat to be supplied by the water is

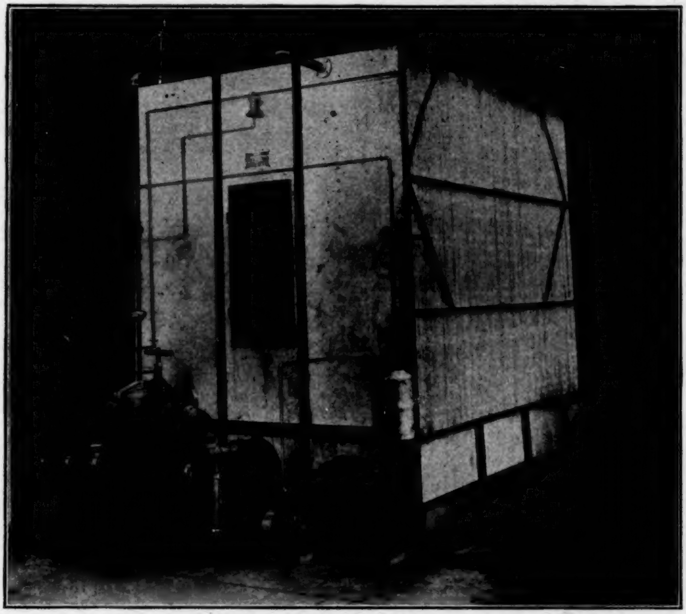
$1{,}000 \times 5 \div 56 = 89$ B. t. u. sensible heat.

$1{,}000 \times (4.8 - 0.25) \times 1{,}080 \div 7{,}000 = 700$ B. t. u. latent heat.

Total heat required $= 789$ B. t. u.

With the washer using 3 gal. of water per 1,000 cu. ft. of air, $789 \div (3 \times 8.33 \times 1) = 31$ deg. drop in water tempera-

ture is required to supply the heat. The conditions of the incoming air are changing constantly and continuously, so that the automatic control system must be extremely flexible to meet the great range of work required, if satisfactory results are to be procured.



THE HUMIDITY CONTROL SYSTEM.

HUMIDITY CONTROL SYSTEM.

The general arrangement of the humidity control system is indicated in Fig. 1. The stem of a graduated thermostat shown at A is placed in the air passage just beyond the eliminators, so that it is exposed to the temperature of the air leaving the washer, and its expansion or contraction is caused entirely by this temperature, and the variation due to its expansion is made to regulate this temperature.

The water heater of the ejector type shown at B is placed in the suction line to the pump. The heater operates like a

barometric condenser, so that the temperature of the spray water is varied by varying the amount of steam furnished to the ejector.

The diaphragm steam valve shown at C is placed in the steam line which supplies the water heater. This valve is operated by compressed air pressure from the graduated thermostat A.

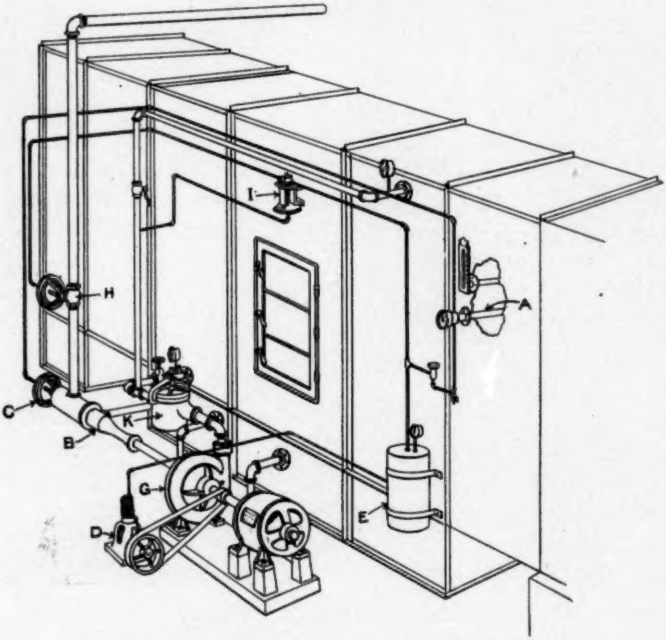


FIG. 1.—GENERAL ARRANGEMENT OF THE SYSTEM.

The air compressor shown at D furnishes compressed air at about 15 lb. pressure to the storage tank E. The compressor is driven by the same motor that drives the spray water circulating pump G.

The reverse acting diaphragm valve shown at H is normally closed, but is opened by compressed air from the tank, E, passing through the safety valve, I.

The pot strainer shown at K is for the purpose of catching any scale or dirt which may be brought from the steam lines.

This method is extremely sensitive, as any variation in the air temperature passing over the stem of the graduated thermostat produces a change in the air pressure of the diaphragm steam valve, causing the valve to partially open or close, thereby producing a new water temperature. In only a few seconds this water is sprayed into the air, affecting its temperature, giving to it more or less heat in accordance with the requirements of the thermostat. This air in about one second passes over the thermostat stem, imparting to it the change in temperature, thereby completing the cycle. The system, while sensitive, is not frail or delicate.

The graduated thermostat usually employed in maintaining a constant dew point is shown in Fig. 2. This consists of an outer expansive member A, usually brass, and an inner non-expansive member B, of nickel steel. These two members are firmly connected at the end C. The other end of the inner member B is provided with a bronze valve D, ground to fit the adjustable valve seat E, supported by the member A. Compressed air is admitted through the connection F, to the annular chamber G, between the inner and outer tubes. As the outer member expands the valve D recedes from its seat, allowing the compressed air to escape into the outlet connection H, which connects with the diaphragm valve controlling the temperature of the spray water, so as to reduce the temperature of the dew point. When the dew point temperature falls below the point desired the outer member contracts, closing off the air supply to the diaphragm valve, connected to H, and the air pressure to the diaphragm motor is released through the adjustable vent J. This vent allows an air leak varying with the pressure on the diaphragm motor. Therefore, the relation of the area of opening through the valve D-E to the constant area of the vent opening J determines the graduated pressure on the diaphragm motor at any instant. This is found in practice to give a very sensitive as well as positive control.

The common difficulty usually experienced in the heating of water by an automatically controlled ejector is the noise produced when very little steam is being used. This noise is a water hammer occurring when a reduced amount of steam at low velocity enters a large volume of water and suddenly condenses.

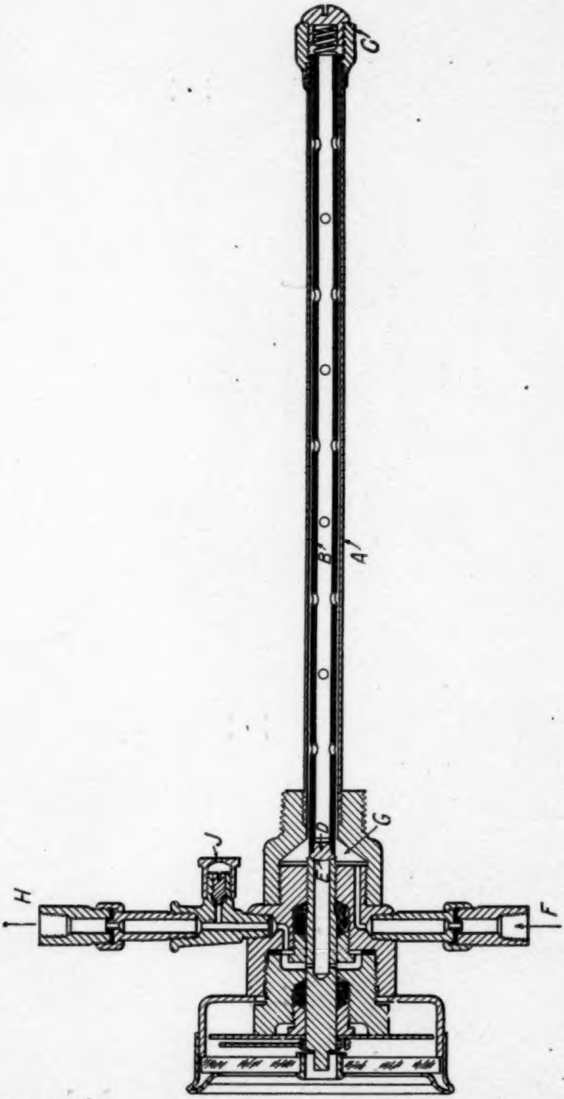


FIG. 2.—SECTION OF THE DEW POINT GRADUATED THERMOSTAT.

This causes a partial vacuum, which the water immediately fills, producing an impact which forces the valve against its seat.

The design of the heater shown in Fig. 3 prevents the hammering of the valve. The diaphragm steam valve is made a part of the heater. The steam enters at A through the valve B into the chamber C; then through the orifice D. The water enters at E and passes out at F. The opening through the orifice D varies with and is approximately equal to the opening of the valve B for all positions of the latter. The valve and conical plug D are on the same stem and their position is controlled by the diaphragm. Air pressure causes the diaphragm to close the valve when too much steam is being supplied; that is, when the temperature of the air at the thermostat is too high. A reduction of air pressure allows the spring to open the valve wider. This water heater is the culmination of five years' experimenting to get an ejector that would be practically noiseless with varying quantities of water. It will operate with steam at 3 lb. or over.

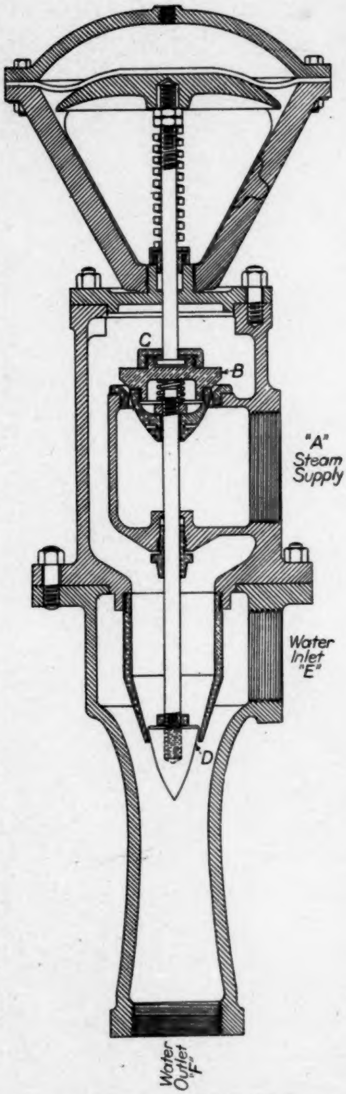


FIG. 3.—EJECTOR WATER HEATER.

Fig. 4 is a section through the reverse acting diaphragm steam valve. This valve is held closed by the spring when the air pressure is relieved or when it is low.

Fig. 5 shows the Carrier combination safety valve. It consists of two small air valves operated by a diaphragm and coil spring. Compressed air direct from the tank enters at the connection A and outlet B connects with the diaphragm of the reverse acting

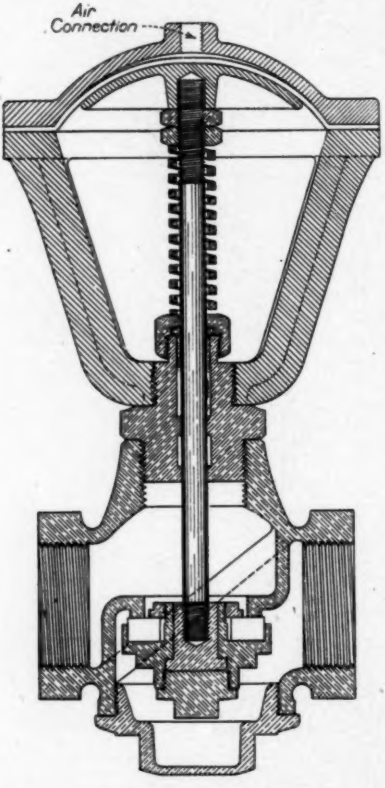


FIG. 4.—REVERSE ACTING DIAPHRAGM STEAM VALVE.

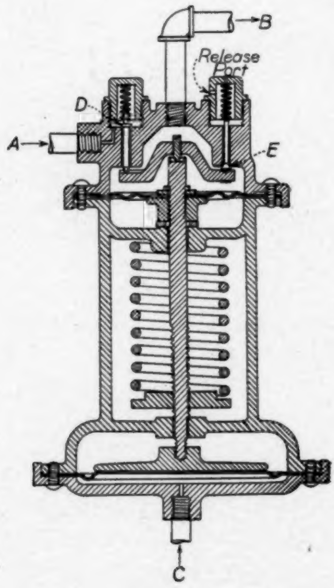


FIG. 5.—COMBINATION SAFETY VALVE.

steam valve. Water pressure from the centrifugal pump is connected to the under side of the metal diaphragm at C.

Should the water pump be shut down or should it for any reason lose its suction, the water pressure is released from under the diaphragm. The spring forces the diaphragm and stem downward, shutting off air pressure by closing the valve D and opening valve E, releasing to the atmosphere the air pressure in

the line running to the reverse acting diaphragm steam valve. The combination of these two valves makes it necessary for the proper air and water pressures to be supplied to the apparatus before any steam can be used in the water heater. This arrangement makes it impossible for steam ever to enter the air currents and over-humidify the building on account of failure of air or water pressure.

Where steam is not available at a pressure of 3 lb. or over; that is, where a vacuum steam heating system or hot water heating is installed, a closed water heater is used. The water passes through the tubes, with the heating medium on the outside. This heater takes up more space and costs more, but is just as efficient as the ejector type of heater which it displaces.

LAWS GOVERNING HUMIDIFYING.

To analyze properly the action of the automatic control attention is called to a few of the general physical laws governing the humidifying of air by means of air washers.

CONDITION NO. 1. *Air is passed through an air washer, with the water being recirculated and not heated.*

The erroneous statement is often made that a washer will give 60 or 70 or 80 or even 90 per cent. relative humidity. This statement is incorrect, as no washer when recirculating the water will give a constant relative humidity to the air leaving, unless the water is heated sufficiently to give complete saturation. The wet bulb temperature of air is always lower than the dry bulb temperature, excepting under conditions of complete saturation. When the air is passed through an air washer the dry bulb temperature is lowered and the wet bulb temperature is unaffected. That is, *the wet bulb temperature is constant.* It is just the same after passing through the water as it was before.

Hence, in Fig. 6, with the air entering at 90 deg. dry bulb temperature and 75 deg. wet bulb temperature, it will be noted that the wet bulb temperature, as shown by the dotted line, does not change when striking the spray, while the dry bulb temperature does change, and drops 9 deg. (down to 81 deg.). The entering difference between the wet and dry bulb temperatures is $90 - 75 = 15$ deg. If complete saturation were procured, the air would be cooled to the wet bulb temperature, giving a cool-

ing effect of 15 deg. The ratio of the cooling done in the above washer to what it is possible to do is $9 \div 15 = 60$ per cent.

The amount of moisture in the entering air is 7.25 grains, while the amount of moisture in the air leaving the washer is 8.57 grains (dry bulb 81 deg., wet bulb 75 deg.). If the humidifier had continued to add moisture until saturation had been procured, the amount of moisture leaving the washer would have been 9.36 grains (saturated at 81 deg.). In other words, the amount of moisture deficiency from saturation in the entering air was $9.36 - 7.25 = 2.11$ grains, and the moisture added to the air in the washer was $8.57 - 7.25 = 1.32$. Therefore, the amount of moisture added was equal to $1.32 \div 2.11 =$ (approxi-

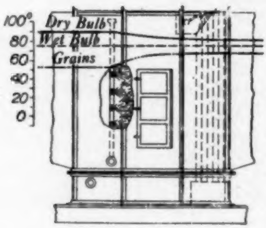


FIG. 6.

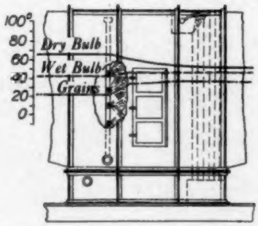


FIG. 7.

mately) 60 per cent. of the amount required to procure complete saturation. Now this same percentage would hold good for this same washer regardless of the difference between the wet and dry bulb temperature of the entering air. That is, the amount of moisture added with *this* washer would always have been 60 per cent. of the amount required to procure complete saturation, and the drop in dry bulb temperature of the air would be 60 per cent. of the difference between the wet and dry bulb temperatures. This factor (in this case 60 per cent.) may properly be called the *humidifying efficiency* of the washer.

The various commercial washers on the market vary in humidifying efficiency from 40 to about 75 per cent., and a fair average may be taken as 60 per cent.

The factors controlling the humidifying efficiency of any washer are:

1. The fineness with which the spray is atomized.
2. The length of spray chamber.

3. The impact with which the water and air meet and are mixed.

4. The relative quantities or weight of air and water used.

CONDITION NO. 2. *Air being passed through a washer with the entering water heated to a temperature above that of the wet bulb temperature of the air.*

When the water is hotter than the wet bulb temperature of the air the immediate effect is an increase in the absolute humidity, with a corresponding increase in the wet bulb temperature, without any change in the dry bulb temperature, until the difference between the water temperature and the wet bulb temperature is reduced a certain percentage (varying with the construction of the washer, the fineness of spray, etc.).

Taking for example Fig. 7; if the air enters at 65 deg. with a wet bulb temperature of 42 deg. and the water at 70 deg., the first action occurring as the air strikes the water is that its absolute humidity is increased and the temperature of the water is lowered. The heat lost from cooling the water is converted into the latent heat for the evaporation of a portion of the water. The difference between the leaving temperature of the water and wet bulb of the air is a certain percentage of the entering difference of the two. The cooling of the water and increasing the wet bulb temperature follows a definite law just as does the cooling of air mentioned in the previous pages. After the water temperature reaches this percentage (varying with the make of washer) of the wet bulb depression, then the air and the water both cool. The additional heat necessary for evaporation is given up by both in cooling of the air and in cooling of the water, thus continuing the increase of the humidity, but with a lowering of temperature.

Fig. 8 traces the action as outlined above. The air enters the washer, as will be noted, at 65 deg. wet bulb, 42 deg. dry bulb, and containing ¼ grain of moisture. The water enters at a temperature higher than the wet bulb and in cooling it increases the absolute humidity from ¼ grain to 3.4 grains. This change on the curve is shown by line AB vertically, there being no change in temperature, but at this point the air begins to give up a part of its heat. Hence, in the evaporation of additional moisture there is a cooling both of the air and water, so that

the action is shown along the line BC. This line is the resultant of the heat procured from cooling the air along the line CE, and the cooling of the water, which would have been shown along the vertical line EC, so that the air would leave the washer under this condition at 58½ deg. temperature, with 56 deg. wet bulb temperature, and 4.8 grains of moisture, which, when heated along the line CD to 70 deg., is equal to 60 per cent. relative humidity.

In the succeeding pages this method of showing the action re-

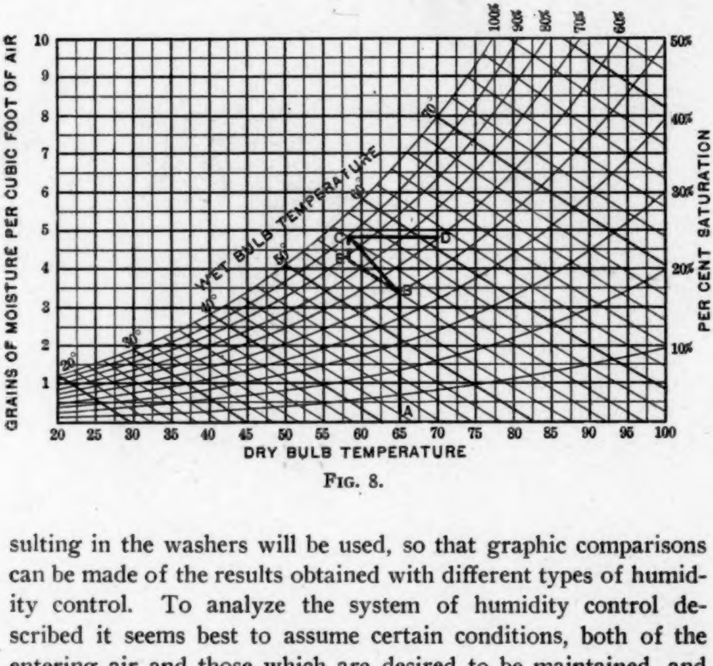


FIG. 8.

sulting in the washers will be used, so that graphic comparisons can be made of the results obtained with different types of humidity control. To analyze the system of humidity control described it seems best to assume certain conditions, both of the entering air and those which are desired to be maintained, and note the results.

Requirements: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *constant saturated temperature leaving the air washer.* Tempering coils controlled by thermostat placed in fresh air inlet, turning on steam to coils at a predetermined temperature of the outside fresh air. Humidifying efficiency of

washer being 60 per cent.; water temperature being varied by a thermostat placed in the path of the air leaving the washer.

The immediate effect of bringing air into contact with water at a higher temperature is that a portion of the water is immediately evaporated without a change in temperature of the air. Where the water is of sufficient temperature it furnishes the heat necessary for evaporation, bringing the air up to the point of saturation. After saturation has been reached, if the water is still sufficiently warm, the evaporation will continue to take place and the air heated at the same time.

Referring to Fig. 10, the air is shown entering at zero with

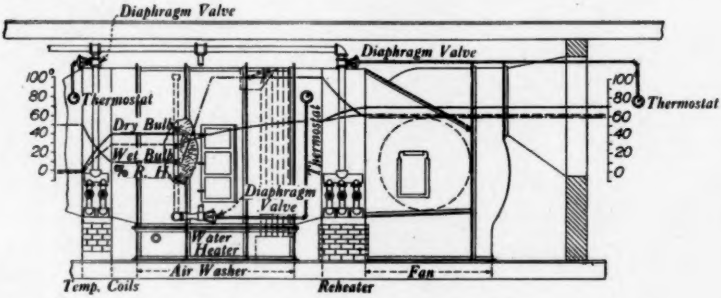


FIG. 9.

a wet bulb of —1½ deg. and containing ¼ grain of moisture per cubic foot, the air being heated by the tempering coil along the dotted line AB to a temperature of, say 40 deg., and the wet bulb to a temperature of 28 deg.

The thermostat at the washer outlet being set for 55 deg., turns on steam to heat the water, which in turn immediately furnishes the heat necessary for evaporation, raising at the same time the wet bulb temperature to the dry bulb temperature, when saturation is procured as shown by line BC, then further raising the temperature and increasing the evaporation until saturation at 55 deg. is procured along the curved line of saturation CE. If the air is then passed through the reheater it is raised in temperature, as shown by the line ED.

With any incoming amounts of vapor and any temperature of 55 deg. or less, the action is always the same; that is, to evaporate the water until saturation is procured and then simul-

taneously evaporate and heat the air along the saturation curve until the same final result is procured; viz., saturation at 55 deg.

With temperatures higher than 55 deg., but containing less than the required amount of vapor, the action would be slightly different; that is, heat necessary for evaporation is procured both from the air and from the water. With an entering temperature

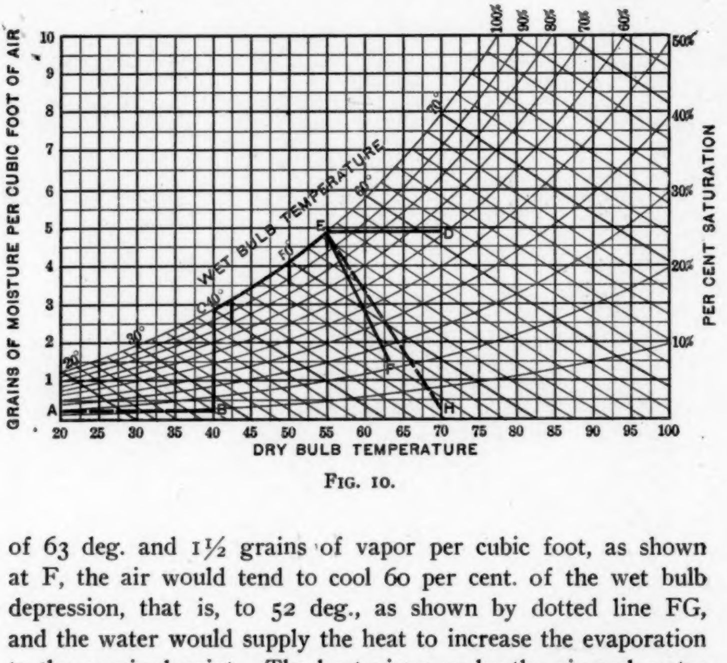


FIG. 10.

of 63 deg. and 1½ grains of vapor per cubic foot, as shown at F, the air would tend to cool 60 per cent. of the wet bulb depression, that is, to 52 deg., as shown by dotted line FG, and the water would supply the heat to increase the evaporation to the required point. The heat given up by the air and water produces a change, as shown by the full line FE.

For a washer with a humidifying efficiency of 60 per cent. the limits for the incoming conditions which will result in giving the required conditions are shown by the dotted line EH. Those entering conditions which are to the left of this line will give correct regulation. If a washer having a humidifying efficiency of 100 per cent. were used, the limits of the entering conditions would be shown by the wet bulb line of 55 deg.

Thus it is seen that this method of automatic regulation is extremely flexible, covering all conditions which would be encountered in the heating season, and is at the same time simple,

practical, accurate and dependable. With this method of humidity control it is not necessary to regulate automatically the tempering coils, as no harm is done if the temperature entering the washer falls below freezing. The coils are used in very cold weather to heat the air to any temperature, say between 25 and 45 deg., and thus relieve the spray water of some of the work.

If automatic control is for any reason desired for the tempering coil or coils, the thermostat should be placed in the fresh air, so it will be exposed to the temperature of the incoming air rather than to the temperature of the heated air. To illustrate: Suppose one coil is thermostatically regulated and this coil has sufficient surface to increase the air temperature, say 15 deg., and the thermostat is set for 25 deg. When the outside temperature falls to 25 deg. this coil will be turned on full and the air heated to 40 deg. When the outside temperature rises above 25 deg. this coil is shut off and the air will go to the washer at temperatures varying between 25 and 40 deg., which is sufficiently close for the humidity control, by this method.

The advantage of exposing the thermostat to the outside temperature rather than to the air leaving the tempering coil is that when the outside temperature falls below 25 deg. steam is turned on to the coil and is left on until the outside temperature rises above 25 deg.

If, however, the thermostat was placed after the coil, whenever the temperature fell below that for which the thermostat was set the steam would be turned on the coil. As soon as the temperature rises a few degrees it would be again turned off. This continual turning on and off of the steam valve gives but little time to establish proper steam circulation, with the result that it is very probable only part of the coil will be heated; so troubles from stratification of cold and hot air will be experienced.

FALLACIES.

As stated in the beginning of this paper, there have been proposed many methods for humidity control which were either wrong in theory or impossible practically. Many of these proposed methods are analyzed in the following, in the same manner, with the same assumed conditions, as in the study of the system just described; so a comparison may be easily made.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *constant temperature entering* the air washer. Tempering coils controlled by thermostat placed at washer inlet. Humidifying efficiency of washer being *60 per cent.;* water being recirculated without heating.

Here the air is shown entering at zero with a wet bulb of —1½ deg. and containing ¼ grain of moisture per cubic foot. The air is heated by the tempering coil to a temperature of 60 deg. and the wet bulb to a temperature of 40 deg. As the

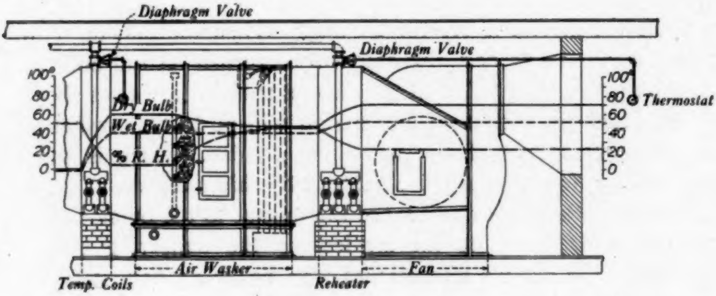


FIG. 11.

washer has a humidifying efficiency of 60 per cent., the temperature of the air drops 60 per cent. of the difference between the wet and dry bulb, or 12 deg.; after which it will pass through the reheater and fan, and then into the duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

Referring to Fig. 12 for the condition as shown in Fig. 11, the air enters the tempering coil under condition as shown in A at zero and ¼ grain of moisture. It is heated along the dotted line AB to 60 deg. with ¼ grain of moisture and a wet bulb of 40 deg. It is then passed through the air washer, where the air is cooled 60 per cent. of the difference between the dry and wet bulb temperatures; that is, to 48 deg., as shown by BC. Then it passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by line CD. It will be noted that the absolute humidity has been raised from

¼ grain of moisture to 1.8 grains of moisture per cubic foot, giving about 22 per cent. relative humidity at 70 deg.

Similarly shown on the same curve are the results that would be obtained by the same washer with entering air at a constant temperature of 60 deg. and containing 1½, 2½, 3½, and 4½ grains per cubic foot. This shows a relative humidity varying from 22 per cent to 60 per cent. Hence, it is readily seen from the above that a *constant entering temperature* will not even theoretically control the relative humidity with varying amounts

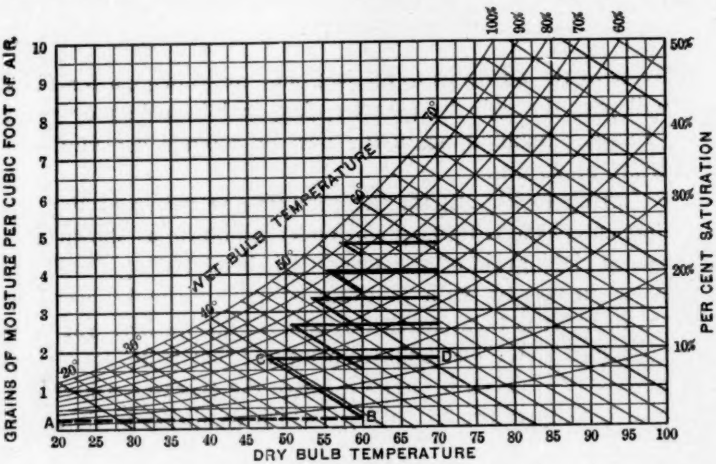


FIG. 12.

of moisture entering the washers. For practical difficulties, see page 450.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *constant temperature entering* the air washer. Tempering coils controlled by thermostat placed at washer inlet. Humidifying efficiency of washer, *100 per cent.;* water being recirculated without heating.

Here the air is shown entering at zero with a wet bulb of —1½ deg. and containing ¼ grain of moisture per cubic foot. The air being heated by the tempering coil to a temperature of 60 deg. and the wet bulb to a temperature of 40 deg. As the washer has a humidifying efficiency of 100 per cent., the tem-

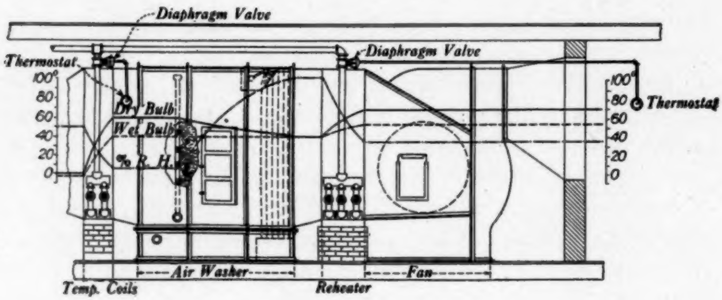


FIG. 13.

perature of the air drops to the wet bulb, or 40 deg.; after which it will pass through the reheater, fan, and into duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

Referring to Fig. 14 for the condition as shown in Fig. 13, the air enters the tempering coil under condition as shown in A at zero and ¼ grain of moisture. It is heated along the dotted line AB to 60 deg. with ¼ grain of moisture and a wet bulb of 40 deg. It is then passed through the air washer, where the air is cooled to the wet bulb temperature; that is, to 40 deg., as shown by BC. Then it passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by

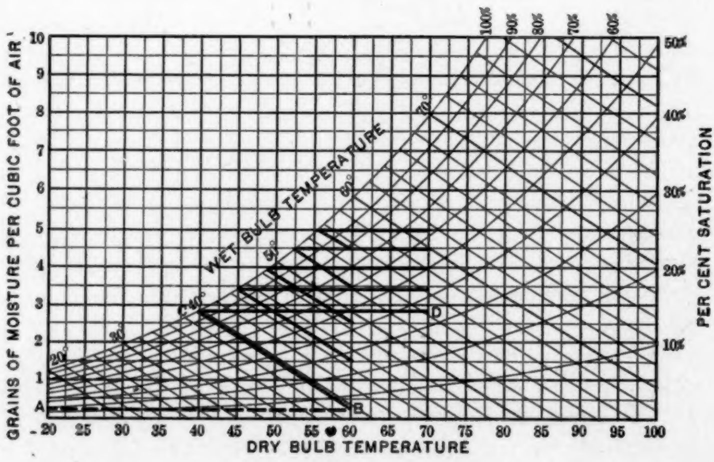


FIG. 14.

line CD. It will be noted that the absolute humidity has been raised from ¼ grain to 2.8 grains of moisture per cubic foot, giving about 35 per cent. relative humidity at 70 deg.

Similarly shown on the same curve are the results that would be obtained by this same washer with entering air at a constant temperature of 60 deg. and containing 1½, 2½, 3½, and 4½ grains per cubic foot, with a constant leaving temperature of 60 deg. This shows a relative humidity varying from 35 to 62 per cent.

Hence, it is readily seen from the above that a *constant entering temperature* will not even theoretically control relative humidity with varying amounts of moisture entering the washers.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *constant temperature leaving* the air washer. Tempering coils controlled by thermostat placed at washer outlet. Humidifying efficiency of washer being *60 per cent.;* water being recirculated without heating.

Here the air is shown entering at zero with a wet bulb of —1½ deg. and containing ¼ grain of moisture per cubic foot; the air being heated by the tempering coil to a temperature of 77 deg. and the wet bulb to a temperature of 48½ deg. As the washer has a humidifying efficiency of 60 per cent., the temperature of the air drops 60 per cent. of the difference between the wet and dry bulb, or 17 deg., to 60 deg., the temperature which is being controlled; after which it will pass through the reheater, fan, and into duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

Referring to Fig. 16 for the condition as shown in Fig. 15, the air enters the tempering coil under condition as shown in A at zero and ¼ grain of moisture and a wet bulb of 48½ deg. It is then passed through the air washer, where the air is cooled 60 per cent. of the difference between the dry and wet bulb temperatures; that is, to 60 deg., as shown by BC. Then it passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by line CD. It will be noted that the absolute humidity has been raised from ¼ grain of moisture to 2.4 grains of moisture per cubic foot, giving about 30 per cent. relative humidity at 70 deg.

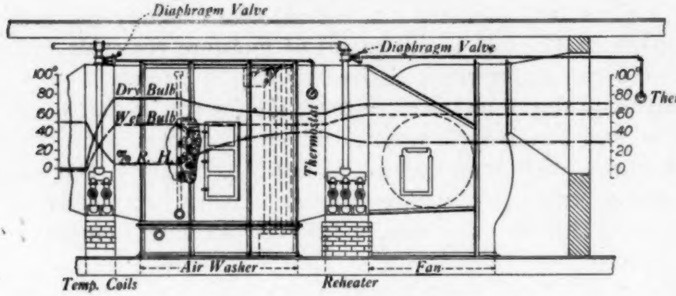


FIG. 15.

Similarly shown on the same curve are the results that would be obtained by this same washer with entering air containing 1½, 2½, 3½, and 4½ grains per cubic foot and with a constant leaving temperature of 60 deg. This shows a relative humidity varying from 30 to 62 per cent.

Hence, it is readily seen from the above that a constant leaving temperature will not control relative humidity with varying amounts of moisture entering the washers.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *constant temperature leaving* the air washer.

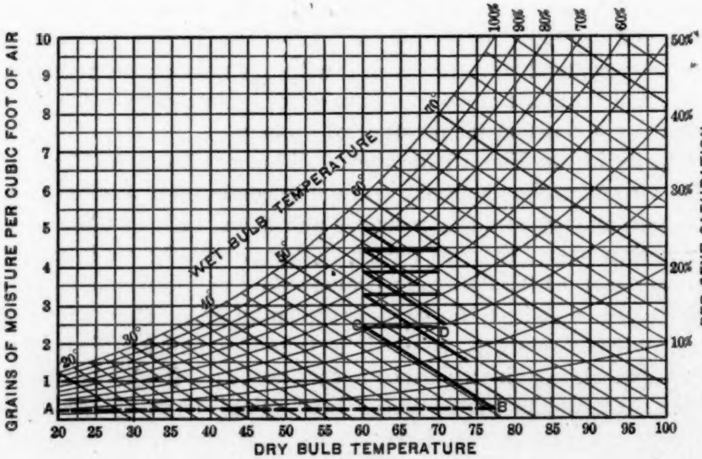


FIG. 16.

Tempering coils controlled by thermostat placed at washer outlet. Humidifying efficiency of washer being *100 per cent.;* water being recirculated without heating.

Here the air is shown entering at zero with a wet bulb of 1½ deg. and containing ¼ grain of moisture per cubic foot; the air being heated by the tempering coil to a temperature of 90 deg. and the wet bulb to a temperature of 55 deg. As the washer has a humidifying efficiency of 100 per cent., the temperature of the air drops to the wet bulb temperature, or to 55 deg.; after which it will pass through the reheater, fan, and into duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

Referring to Fig. 18 for the condition as shown in Fig. 17, the air enters the tempering coil under condition as shown in A at zero and ¼ grain of moisture. It is heated along the dotted line AB to 92 deg. with ¼ grain of moisture and a wet bulb of 55 deg. It is then passed through the air washer where the air is cooled to the wet bulb temperature; that is, to 55 deg., as shown by BC. Then it passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by line CD. It will be noted that the absolute humidity has been raised from ¼ grain to 4.8 grains of moisture per cubic foot, giving about 60 per cent. relative humidity at 70 deg.

The air leaves the washer saturated at the wet bulb temperature of the entering air. The thermostat continues to increase the steam supply to the tempering coil to raise the temperature, until the wet bulb has reached 55 deg., at which point the temperature is controlled. Similarly shown on the same curve are the results that are obtained with any number of grains entering, so long as the wet bulb temperature does not exceed 55 deg.

Here is shown a control that is theoretically correct, but which has some unsurmountable objections from a practical standpoint discussed on page 452.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by *varying the temperature entering the air washer by means of a hygrostat.* Hygrostat placed in room or in air duct, the temperature of which is maintained constant. Humidifying efficiency

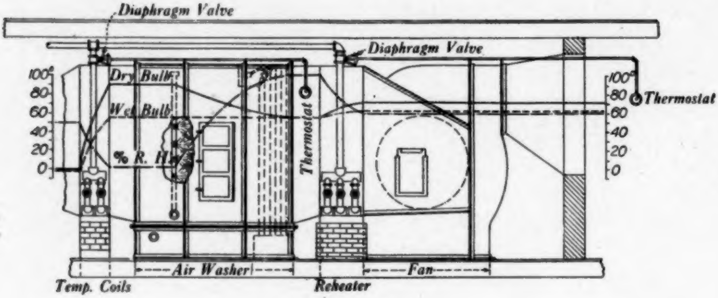


FIG. 17.

of washer being *60 per cent.;* water being recirculated without heating.

Here the air is shown entering at 50 deg., with a wet bulb of 47 deg., and containing 3½ grains of moisture per cubic foot; the air being heated by the tempering coil to a temperature of 75 deg. and the wet bulb to a temperature of 59 deg. As the washer has a humidifying efficiency of 60 per cent., the temperature of the air drops 60 per cent. of the difference between the wet and dry bulb, or 10.6 deg.; after which it will pass through the reheater, fan, and into duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

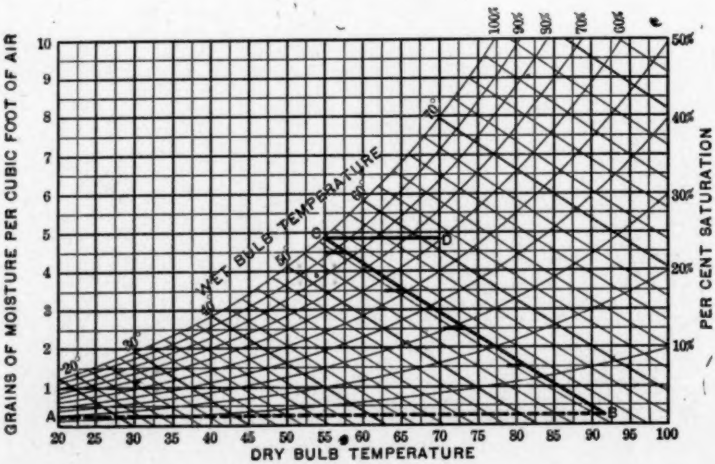


FIG. 18.

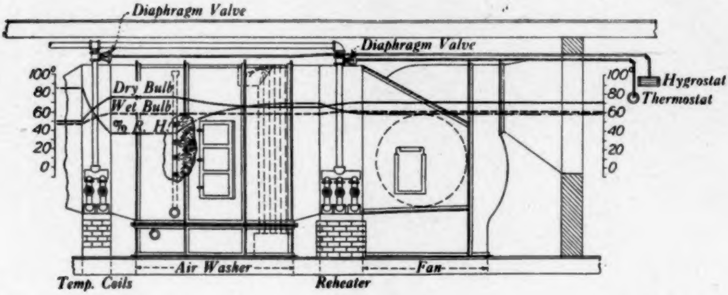


FIG. 19.

Referring to Fig. 20 for the condition as shown in Fig. 19, the air enters the tempering coil under condition as shown in A at 50 deg. and 3½ grains of moisture. It is heated along the dotted line AB to 75 deg., with 3½ grains of moisture and a wet bulb of 59 deg. It is then passed through the air washer, where the air is cooled 60 per cent. of the difference between the dry and wet bulb temperatures; that is, to 65.4 deg., as shown by BC. Then it passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by line CD. It will be noted that the absolute humidity has been raised from 3½ grains of moisture to 4.8 grains of moisture per cubic foot, giving about 60 per cent. relative humidity at 70 deg.

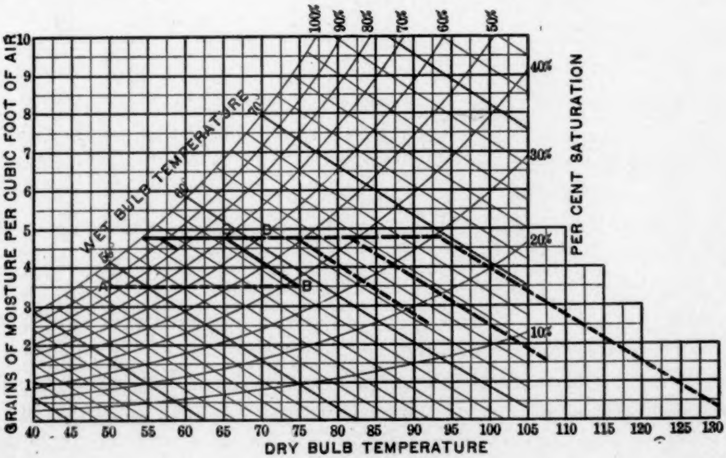


FIG. 20.

Similarly shown on the same curve are the results that would be obtained by this same washer with entering air containing 1½, 2½, 3½, and 4½ grains per cubic foot, with the inlet temperature varied by a hygrostat which is exposed to the air after it has been heated to a constant temperature. It will be noted, however, when the vapor contents of the incoming air are lower than 3.2 grains that the temperature rise in the tempering coil necessary to procure the evaporation is so great that the air in cooling does not get down to 70 deg., even though steam is shut off the reheater.

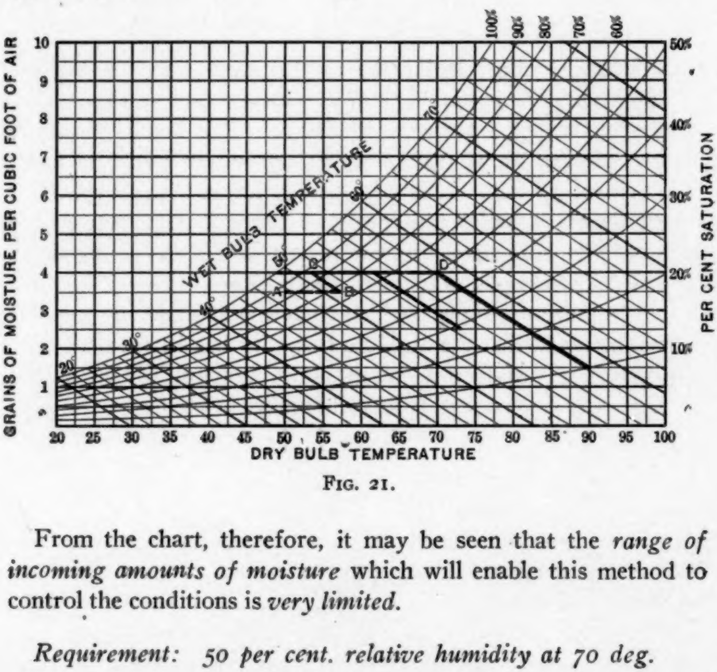


FIG. 21.

From the chart, therefore, it may be seen that the *range of incoming amounts of moisture* which will enable this method to control the conditions is *very limited.*

Requirement: 50 per cent. relative humidity at 70 deg.

CONDITIONS: Same as for Fig. 6. Fig. 21 is similar to Fig. 20 and the arrangement of the control is identical with that shown in Fig. 19, but the requirements being changed from 60 per cent. to 50 per cent. relative humidity.

Fig. 21 shows that this arrangement will give for low relative humidities *theoretically correct regulation* for all incoming amounts of water vapor *between 1 1-2 grains and 3.2 grains,* provided the requirements are low, *i. e.,* below 50 per cent.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Same as for Fig. 19, excepting washer has a humidifying efficiency of 90 per cent.

The arrangement of the control is exactly like that shown in Fig. 20, except that the humidifying efficiency of the air washer is taken at 90 per cent. instead of 60 per cent. Fig. 22 shows that this arrangement will give *theoretically correct regulation between rather large limits.*

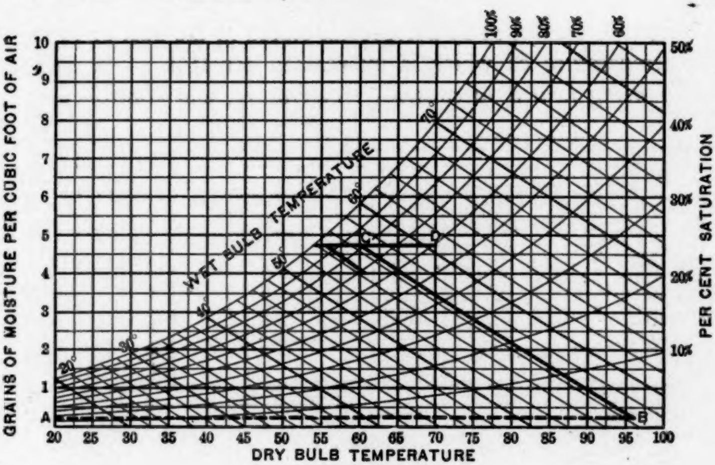


FIG. 22.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by *varying the temperature entering the air washer by means of a hygrostat.* Hygrostat placed in air duct or in room, the temperature of which is maintained constant. Humidifying efficiency of washer, *100 per cent.;* water recirculated without heating.

Here the air is shown entering at zero, with a wet bulb of —1½ deg. and containing ¼ grain of moisture per cubic foot; the air being heated by the tempering coil to a temperature of 90 deg. and the wet bulb to a temperature of 55 deg. As the washer has a humidifying efficiency of 100 per cent., the temperature of the air drops to the wet bulb temperature, or 55 deg.; after which it will pass through the reheater, fan, and into duct

or room, the reheater maintaining in the room or duct a constant temperature of 70 deg.

Fig. 18 shows the variation in temperature for this method, and all remarks applying to that curve are equally true of this method.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by maintaining a *variable temperature entering the air washer,* tempering coils controlled by a hygrostat placed in the duct or room, the temperature of which is maintained constant. *The spray water being heated to constant temperature,* and controlled by

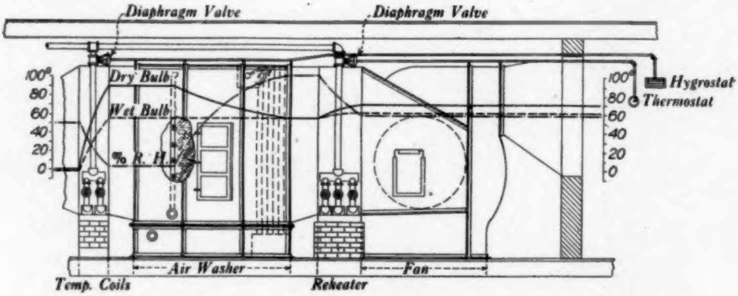


FIG. 23.

a thermostat. The humidifying efficiency of the washer being *60 per cent.*

Here the air is shown entering at zero, with a wet bulb of —1½ deg. and containing ¼ grain of moisture. The air being heated by the tempering coil to a temperature of 80 deg., with a wet bulb temperature of 49½ deg. As the washer has a humidifying efficiency of 60 per cent., the air tends to drop to 60 per cent. of the difference between the dry and wet bulb, but, as the water is also heated above the temperature of the entering wet bulb, there is an evaporation due to the heat being supplied by the water, which greatly increases the amount of moisture delivered by the washers. After the air has been humidified it passes through the reheater, fan, and into the duct or room, the reheater maintaining in the duct or room a constant temperature of 70 deg.

Referring to Fig. 25 for the condition as shown in Fig. 24,

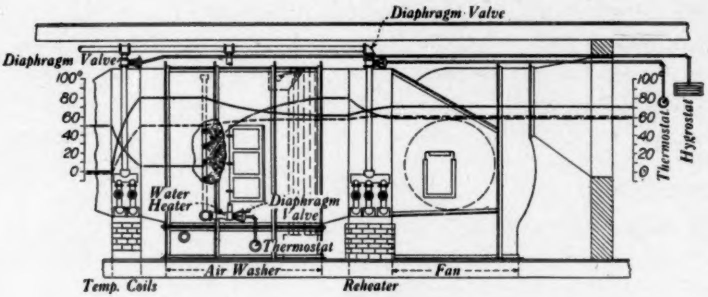


FIG. 24.

the air enters the tempering coil under a condition as shown at A at zero and ¼ grain of moisture per cubic foot. It is heated along the dotted line AB to 80 deg., with ¼ grain of vapor per cubic foot and a wet bulb temperature of 49½ deg. It then passes through the air washer, where the air is cooled down to the temperature of the water, which in this case we have taken as 75 deg. The result from this point is a combination of the evaporation due to the heat given up by the water and the heat given up by the air. The air in delivering heat to evaporate the vapor is cooled to 60 per cent. of the difference of the wet and dry bulb temperatures, while the water delivers heat to produce evaporation depending on the difference between the incoming

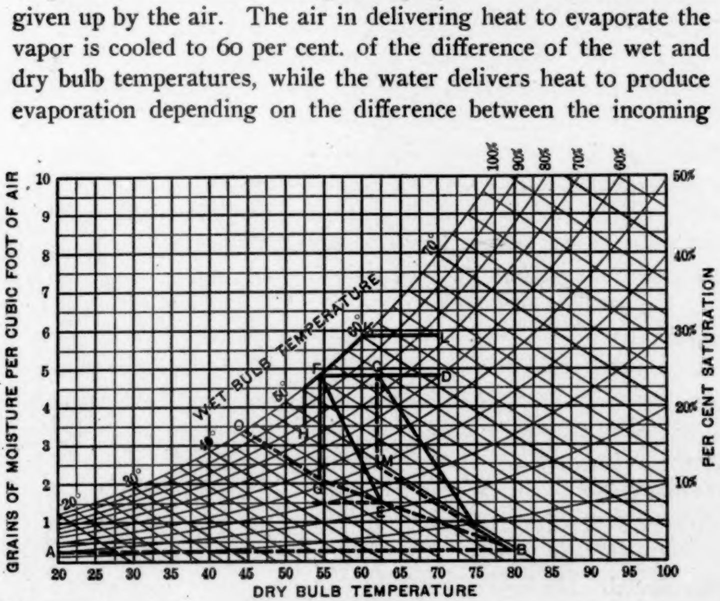


FIG. 25.

wet bulb temperature and the water temperature. These two acting separately would be along the dotted line BMC, the resultant of the two being along the full line BC, giving a temperature leaving the washer of 62 deg., with 4.8 grains of moisture per cubic foot. It then passes through the reheater, where it is raised in temperature to 70 deg., which condition is shown by line CD, giving 60 per cent. humidity at 70 deg.

Similarly, if the air is heated to 62½ deg., with 1½ grains of moisture per cubic foot entering the washer, the result will be 4.8 grains of moisture per cubic foot, giving 60 per cent. humidity at 70 deg. If the amounts of moisture entering are as large as 3½ grains at 52½ deg., as shown at H, the amount of heat delivered to the air by the water is greater than that required to get the necessary evaporation. Hence, the resultant will be to heat the air to saturation, then along the saturation curve from F to K, where it will leave the washer and pass through the reheater, and be heated to 70 deg. to L, giving 75 per cent. of humidity at 70 deg.

It will be noted that with the relative temperature of water and air and the amount of vapor entering the washer that the humidity could be controlled with low incoming amounts of moisture without being able to maintain the proper humidity under high entering amounts of moisture. The dotted line extending from BEGO shows the limits of the control as set in this case. That is, if the air entering the washer with a temperature and humidity which would bring it on the right or above this dotted line would give more humidity than desired, while a temperature and humidity to the left would give proper automatic control, as the tempering coil could raise the temperature to that necessary to evaporate the amount of moisture required.

From the above it will be seen that with *a variable temperature entering the washer,* controlled by a hygrostat with a *constant water temperature,* the control of humidity is within very narrow limits, and while these limits can be shifted, it is impossible to cover a reasonable range with this arrangement.

Requirement: 60 per cent. relative humidity at 70 deg.

CONDITIONS: Endeavoring to procure constant humidity by *varying the water temperature by means of a hygrostat placed*

in the path of the air after it has been heated with a thermostat also placed in the path of the air to control the temperature.

The thermostat shown in the air duct controls the steam supply to the heating coils, thereby theoretically regulating the temperature of the air passing through the duct in which the thermostat and hygrostat are placed. The hygrostat controls the steam supply to the water heater by operating the diaphragm valve. Here the air is shown entering at zero, with a wet bulb of $-1\frac{1}{2}$ deg. and containing $\frac{1}{4}$ grain of moisture per cubic foot; the air being heated by the tempering coil to a temperature of say 40 deg., and the wet bulb to a temperature of 28 deg.

The hygrostat in the air duct being set for 60 per cent., turns on steam to heat the water, which in turn immediately furnishes the heat necessary for evaporation, raising at the same time the wet bulb temperature to the dry bulb temperature, when saturation is procured, then further raising the temperature and increasing the evaporation until saturation at 55 deg. is procured. Refer to Fig. 10, which shows the variations in this case also.

The first action is to increase the humidity, as is shown by the vertical line AB, until complete saturation is procured. Then additional evaporation and heating is procured along the curved line of saturation BC. If the air is then passed through the reheater it is raised in temperature, as shown by the line CD.

The regulation of the temperature in the air passage or duct is just about as difficult as the troubles described in controlling tempering coils, as explained on page 453. If a positive operating valve is used every time the valve is opened or closed, the temperature must vary several degrees. Every time the temperature changes a new condition is imposed on the hygrostat.

To illustrate: Suppose the thermostat is set for 70 deg. and the hygrostat for 60 per cent. relative humidity. If the temperature runs slightly above 70 deg., the thermostat would turn off the steam, allowing the temperature to fall. Now, if the hygrostat was maintaining the evaporation at the desired point before the change in temperature, it would immediately lower the evaporation, as with the new and lower temperature the humidity passing the hygrostat would be very much higher. These unstable conditions cannot even approximate accurate regulation.

If the thermostat used to control the temperature of the heater

is of the graduated type, then the variations of the air temperature passing over the thermostat will be held more constant, but as this method at times only fills a part of the heating coil with steam, the temperatures will be quite different in various parts of the duct. So, if the humidity is controlled correctly in the strata of air passing over the hygrostat, it would not be controlled in the strata having a different temperature.

Another very important point is the type of hygrostat used. To be even reasonably accurate, this instrument must operate on the wet and dry bulb principle, which is in itself an added complication for this kind of work. Any hygrostat operating on the hygroscopic properties of some material is inaccurate. As it requires some time for it to absorb or evaporate moisture, it is continually "lagging" behind the true condition; also its hygroscopic properties are continually changing from the day it is installed, due to change in its molecular construction and to dust filling the pores.

PRACTICAL DIFFICULTIES IN THE REGULATION OF A TEMPERING COIL.

It has been seen that humidity may be regulated theoretically by the methods shown by Figs. 17 and 18, 19 and 22, and within limits by Figs. 24 and 25, but these methods all depend upon the regulation of the temperature of the air entering the washer. The actual regulation of this temperature in practice is a most difficult problem, although it has been repeatedly tried.

Bypass Dampers: The first method which would naturally suggest itself is to use a bypass damper over or under the tempering coils. This cannot be used on account of stratification. The air entering through the tempering coil and through the bypass damper would have different temperatures, and while in going through the washer these temperatures would be changed, they still would be different, and that difference probably as great as on entering the washer.

Air passing through an 8 in. vertical space between two tempering coils has been known to freeze a solid cake of ice 4 in. wide upon the eliminator plates of the washer 6 ft. away. The air passing through the tempering coils was heated to 40 deg. and the spray water was also heated, so the balance of the air was leaving the washer at 45 deg. The thermostat controlling

the temperature of the air was in the path of the air which had passed through the tempering coil.

Unless the fan is placed between the tempering coils and washer so it will be mixed and all stratification removed, the regulation of the temperature entering the washer by means of a bypass around the tempering coils is not practical. In fact, it might be said to be impossible.

To place the washer on the pressure or discharge side of the fan is very objectionable, as any leakage of air from the washer carries water from the spray out with it. If the washer is on the suction side, however, any air leakage is inward and the doors of the washer may be opened for inspection while it is in operation, without any water coming out on the observer.

Regulating Steam Supply to Tempering Coil: The automatic operation of a steam supply valve to a tempering coil must be positive and complete to be practical. The valve must be opened sufficiently wide to entirely fill the coil or it must completely be closed off. Any intermediate or graduated action which does not allow of completely filling the coil with steam is sure to cause trouble in cold weather. A part of the coil would be filled with steam and be hot, while the rest of the coils would be cold. The condensed steam is often held in the coil, due to the high vacuum thus produced, and is frozen in the cold part of the coil by the very cold air passing over it. Valves that were partially open have been known to furnish sufficient steam to one end of a tempering coil to heat the air well above freezing, while the condensation froze and cracked the base at the cold end.

From this it is very evident that any method of humidity control with an air washer must operate the steam valve positive from full open to closed position, or vice versa. In all the methods mentioned which depend upon the operation of a tempering coil and which will even theoretically give automatic regulation of humidity, the incoming air must be heated to at least 90 deg. on a zero day, with ¼ grain of vapor per cubic foot of incoming air. Pardon the slang, but this requires "some tempering coil, believe me," with its attendant resistance to the air passage.

Now the question comes, How is it to be automatically regulated? Consider the best way to do it first, and see how bad that way is, and probably a further discussion will be unneces-

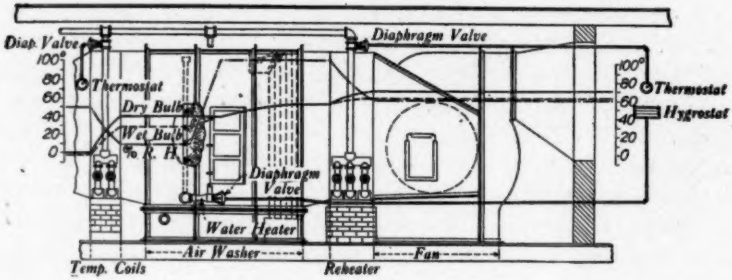


FIG. 26.

sary. This tempering coil must of necessity (in order to accomplish the desired result, that of automatically controlling reasonably close the relative humidity) have the steam supply so regulated that the temperature of the air entering the washer will be maintained within a range of say 2 to 3 deg. of that required by the regulator. One section of the usual types of tempering coils with an air velocity of 1,000 ft. per minute and steam at atmospheric pressure will heat the air at the very least 15 deg. Let us consider, therefore, that the regulator is operating the steam supply to only one section of the tempering coil, and that the other sections (at least five others being required) could be and are carefully watched and regulated by hand.

Referring to Fig. 27, the air would enter the automatically

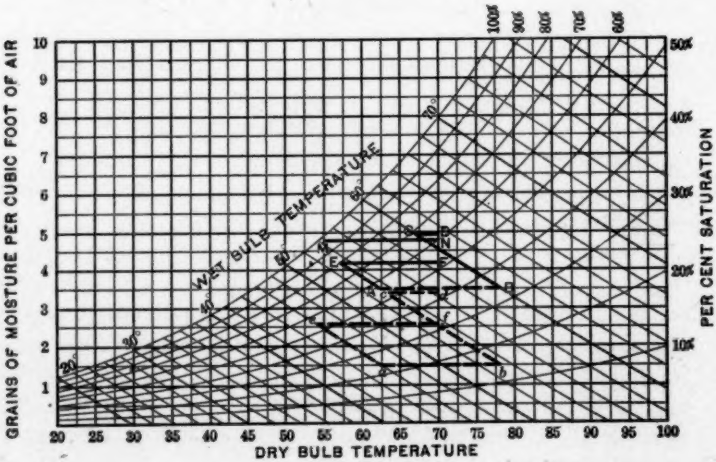


FIG. 27.

controlled section of the tempering coil at 62½ deg. and be heated to 76 deg., shown by dotted line AB. In passing through the washer moisture is evaporated and the air cooled (along BC) to 67 deg., with 4.9 grains of vapor per cubic foot, giving 62 per cent. humidity at 70 deg. However, the regulator is set for 60 per cent. humidity at 70 deg., which is equal to 4.8 grains per cubic foot, as shown by line MN. The regulator would, of course, tend to lower the temperature given by the tempering coil in order to reduce the humidity, and when it acts it must close off this section, allowing the air temperature to drop to 62½ deg. at A, which will be cooled in passing through the washer to 57 deg. (shown by line AE), with only 4.2 grains of vapor per cubic foot, which is equal to 52 per cent. at 70 deg.

Some will say, "controlling the humidity within 10 per cent. is plenty close enough for me," and in a great many cases they are right, but the worst is yet to come. In the above discussion we were considering the air was leaving the tempering coils, which were hand controlled, at 76 deg. temperature and 3½ grains of vapor per cubic foot and was heated in the last section to 62½. Now, suppose during the day the vapor content of the outside air falls from 3 grains to 1½ grains per cubic foot, without any change in temperature, so the air will still leave the coils, which are being regulated by hand, at 62½ deg. The results are then shown by the dotted lines, giving a relative humidity of 32 per cent. Mr. Engineer should now turn on an additional coil and heat his air higher. If he did, then the control would alternate between having the air enter the washer at 76 deg., giving 42 per cent. humidity at 70 deg., but how is he to know this, even if he had the time to watch it closely? The instrument that will do it automatically has not yet been invented, and, even if it had been, it would be a very awkward way to accomplish the result.

If the regulator controls two sections poorer regulation would be procured. Any arrangement of this kind is not sufficiently flexible to meet even very slight changes in the fresh air conditions, nor at its best does it give an approximate accurate regulation. Hence, the automatic regulation of humidity within reasonable limits by varying the temperature entering an air washer by operation of the steam supply to the tempering coil is practically impossible.

DISCUSSION.

Mr. Soule: I would like to ask Mr. Lyle if he intends to state that tempering-coils should not be used at all, or if they should be used in addition to warming the water in the washer?

Mr. Lyle: I am a believer in tempering coils. I think they should be used. We recommend tempering coils but we do not recommend controlling them, that is, not attempting to control the humidity by means of tempering coils nor controlling the tempering coils by means of the thermostat placed in the path of the air that has been heated. If the tempering coils are to be automatically controlled, as I said in another part of the paper, then the thermostat should be placed in the fresh air inlet, so that when the steam is once in the coil it stays on until the outside temperature rises above the point at which it is set. If the tempering coils are operated by means of a thermostat placed in the path of the air that has been heated, they are continually going on and off, which is sure to cause trouble.

Mr. Williams: I had a little experience with air washers last winter that made me reflect considerably regarding them. I ran across a specification written by an engineer which read like this: "That, at or below a temperature of 55 deg. on the outside, the relative humidity shall not vary more than between 50 and 60 per cent of saturation," and if you ever saw a picnic that was one. That gave you no reasonable leeway whatever; it must be between 50 and 60 per cent at 55 deg. or below. This happened to be a bank building. I am simply citing it because I think sometimes engineers are drawing on their imaginations in regard to the working of such apparatus, and when the contractor tries to comply with such specifications he gets into difficulties through it. I wish to say that the firm with which I was connected is not yet paid for all that was due it, and much of it was caused by this part of the specifications. In fact, there was nothing else.

I am very glad to have Mr. Lyle's suggestions regarding the placing of the thermometer right in the cold air inlet. The manufacturers of the apparatus in question claimed that they must have 55 deg. of temperature between the tempering coil and the air washer, so they could do their work. Here was the difficulty that was met and what upset all their calculations.

I suppose that they might have come reasonably close to doing what the specifications provided, under ordinary conditions, but the room to be treated was out of the ordinary. In real cold weather we were possibly accomplishing our results; but when you came to a temperature along say, from 35 deg. to 55 deg. our difficulties commenced. Here was a building which, if it could have been kept closed, the apparatus might have come near doing what was required of it because then it would have practically had a constant quantity of air to deal with. But being a banking room there was a door that was opening from the outside, I would say on an average every minute. With the outside air at or near the saturation point, this apparatus was supposed to keep this room between 50 and 60 per cent of saturation, notwithstanding that the doors constantly opened from the outside and admitted air that was thoroughly saturated.

Now I think a specification like that should never be written by an engineer, and I hope that this engineering society will not draw any kind of a specification like that in the future. It is next thing to an impossibility. In fact, I know that it cannot be accomplished.

Mr. Soule: I would like to have Mr. Lyle tell us something about the reheating coils and the use of by-pass dampers underneath. I think that that is something that we ought to have his opinion on.

Mr. Lyle: In the control of reheating coils you do not run across the same difficulties that you do in controlling the tempering coils, due to the fact that your air is always above freezing. You do not have the troubles of freezing up of tempering coils. The question of controlling reheating coils or having bypass dampers for the reheating coils is simply a question of mixing the air and getting the proper temperature in your room. That is a very much easier problem than the control of tempering coils. If the latter are controlled by the use of bypass dampers, as I stated in the paper, or in connection with the air washers, it is absolutely impossible, due to stratification. I have seen in some tests that I have made on running installations where the bypass dampers have been insisted upon by the engineer, temperatures as much as 20 deg. difference between the top and the bottom of the washer, due to the high temperature

going through the tempering coil and the low temperature underneath through the bypass damper; and I have seen it freezing up solid so no air could pass through the bottom of the eliminator. Now your thermostat or hygrostat, whatever you are using to control it, is not spread over the entire surface of the outlet of your washer and it can only be on one point, and it is either in the path of the heated or cold air, and for that reason you must have the air entering the washer uniform in temperature over the entire surface. If you do not, your leaving condition will be different and your controlling device will not be subjected to the proper conditions.

Mr. Ellis: Would not the desired result be obtained if the sections of the tempering coils are turned on one after the other?

Mr. Lyle: As far as the controlling of the temperature is concerned, using the relay and turning on one section after another will give you temperature control within fair limits, say within 10 or 15 deg. at the most. You turn on one section and one off. But when it comes to controlling humidity that way it is rather hopeless; because the humidity does not depend on the entering temperature alone; it depends on the combination of the entering temperature and entering humidity, and you might be holding your temperature correct and the humidity change, just as I stated in the last of the paper, the part I read, and your conditions would be entirely wrong and your results be away off in humidity control.

Mr. Ellis: Now let me ask this question: There are thermostats which in one instance Mr. Lyle speaks of as relay thermostats, and the manufacturers of these thermostats call them multiple thermostats. That is to say, the thermostat will open and close the valves of different sections of tempering or heating coils (open them wide and close them tight), but at different degrees of temperature desired. For instance, with four sections of tempering coils, you can turn one at 68, one at 69, one at 70 and one at 71, and shut them off in reverse proportion. Now there are instruments called hydrostats and humidistats. Suppose they were built on the same plan: would they accomplish the purpose?

Mr. Lyle: Probably. If they were turned on in that way. By applying a multiple hydrostat to a constant temperature, you

would get control of the humidity probably within say 15 per cent. By means of the thermostat you would not get it within 30 per cent.

Mr. Ellis: You spoke of controlling from the intake. Would that make any difference?

Mr. Lyle: Not so far as control is concerned. It relieves some of the work of controlling the washer, which is a somewhat safer proposition.

Mr. Ellis: Would the introduction of two sets of tempering coils make any difference? I have in mind an installation in the La Salle Hotel in Chicago. They have a very elaborate system there. I do not know that they attempt to control the humidity, but the requirements are to produce a temperature somewhere between 40 and 50 deg. for the air entering the air washer. That was done by controlling two or three sections of the first tempering coil by a thermostat located practically right near the air washer. There is no by-pass damper at all. This arrangement is intended to shut off the inside section at a temperature of 40 or 42 deg., and the outside section, the one nearest the air washer, at 45 deg. The air, after going through the air washer, passes through another tempering coil. This latter tempering coil is controlled by a thermostat located in the air chamber, which was set for about 65 or 67 deg. and shuts off those two sections in that order. Now the main heating coils were controlled from the outside. They were in three sections. Half were shut off at 20 deg. above zero, half of the remaining half was shut off at 40 deg. and the balance shut off when the temperature outdoors went up to 70 deg.

I never made any tests, or figured out what the effect on the humidity was.

Mr. Lyle: The result was this: you had a thermostat in the tempering coil set for 40 deg. If the outside temperature dropped to say 38 deg. the thermostat would turn on one section and immediately after that section started to heat it warmed up the air say 15 deg. anyway, it would run that temperature up to 53 deg., so that as soon as it starts the thermostat shuts it off again. It is on or off, back and forth, one way or the other. If you drop down 25 deg. outside it will turn on and stay on, because it will not heat from 25 deg. up above 40 deg., which the thermostat is set. But any place between 25 and 40 deg. it

is continually going on and off, with the result that the valve is continually closing and opening; and it is that kind of thing when you get down below 32 deg. that causes freezing on the tempering coils and causes so many of them to crack. You do not get circulation established. Your thermostat is placed at one side of the air duct and washer, on the side at which the steam enters the coil, so it is affected immediately, and probably no steam reaches the back end of the tempering coil; it is always cold until it gets to the point where it is turned on full and left on. I have seen valves that were put in that way that would operate for hours at half minute intervals.

Mr. Ellis: I never noticed that variation in temperature in the air going into the washer in this plant. They held that between 40 and 45 deg. all winter. They had a recording thermometer on it a great deal of the time.

Mr. Lyle: Have you ever taken readings on the air washer, the temperatures at the inlet and the outlet? I agree with you that if you put your thermostat right on the washer you can control that temperature all the time. But I will not agree that over on the far side of the coil it has been held within 10 or 15 deg. That is the point. It is a fact that your thermostat is not extending over the entire area of the tempering coil. Of course where vacuum systems are used conditions are very much better; but the vacuum systems cannot do wonders.

Mr. Ellis: The valves being opened wide makes little difference from having them opened gradually. If you open them gradually you would get a slow circulation. If you have a large valve and opened wide instantly, with a good vacuum, you would have a good result.

Mr. Davis: I experienced just exactly the thing described by Mr. Lyle last winter, and while I am not positive, I think there was constant automatic regulation on it. It was a large city hall, and had also a return line vacuum system. Of course after they experimented awhile by the changing around of the thermostat they got better results; but in the extreme cold weather we had there, with the thermometer 8 to 12 deg. below zero, they sometimes froze up the washer; and it was due to just exactly the causes that Mr. Lyle describes, that the steam would not get clear through the heaters before the thermostat would shut off the steam. But after it was changed

around so that the thermostat produced its effect by the temperature at the far end of the coil they had less trouble.

Mr. Williams: I would like to ask Mr. Lyle this question: would we not accomplish better results from a moisture standpoint if we controlled our moisture apparatus after the heating was done? I can see difficulties in the way but I do not believe they are insurmountable. You have to furnish the heat necessary to heat the building; and you have to turn on enough of the reheating coils to accomplish these results. Now the more reheating coils you turn on, certainly the dryer the air becomes. With the ordinary washers, the only ones I know of, you are adding your moisture before you have your heating done. It does seem to me that we are putting the cart before the horse.

Mr. Lyle: It is true the more heating coils you put on the higher the temperature of the air and the more moisture the air will hold. On the other hand, the better method—I believe practically all the engineers who have made a study of the subject will agree with me—is to fix the amount of moisture and then heat as you please; because you are maintaining constant room temperatures in the most of those buildings, and it does not matter how high you may heat your air, you do not take any vapor out of it, but simply carry it. That is, we talk of the same temperature of the room; it may be 90 or 100 deg.; but if you are maintaining your room temperature the same, with the same quantity of moisture, it will always be the same relative humidity, and very much more accurate results will be secured by fixing your moisture first and then doing the heating.

Mr. Williams: I will admit that I see the difficulties in the way; but when I go into a heat, or blast chamber, and get thoroughly drenched, after the moisture regulation is supposed to have taken place and all reheating coils are on, I am inclined to think that you are either not accomplishing the results or you are on the wrong track.

Mr. Soule: I would like to ask Mr. Lyle one more question. Considering a schoolhouse heating system, entirely blast heating, where we have four sections deep of reheating coil, with plenum chamber, by-pass damper, mixing chamber, and humidity control, is it not absolutely necessary to pass the air through

an additional coil without any damper in order to limit the humidity to 95 per cent, so as not to send wet air into the room?

Mr. Lyle: That is a very good point. It is absolutely necessary that in any plant where they use a double duct system there should be a tempering coil placed between the washer and the fan, probably only a single section. We had a case this past winter in a hospital building where there was no tempering coil placed between the washer and the fan; and at times the thermostatic regulation placed in each room would throw the mixing damper so that it would take entirely the tempered air. That air started at about 50 deg., I think. Some of the ducts came up along the outer wall and in under the windows, and the walls were very thin, with the result that the air was very cool; and when it came into the room they had a real fog down below the dewpoint, so it would shoot across the room 6 or 8 ft. before the fog would disappear, and in that case a tempering coil had to be placed in there before the trouble was cured.

Mr. Fenstermaker: I agree with the author that it is very difficult to control a tempering coil so that you can control the temperature of the air leaving the fan accurately within a range of 10 or 15 deg. But the main objection seems to be the freezing up of the tempering coils. Suppose the tempering coils are broken up into smaller units, using, for instance, one or two-pipe sections, or, if the Vento type is used, 40-in. instead of 60-in. to supply the tempering coils on each side, and equipped with a reliable thermostat. It would seem, with that arrangement, that a more uniform temperature of the air delivered from the tempering coils would be obtained, and then a portion of the air leaving the tempering coils could be taken care of by means of the control of the water in the air washer itself.

Mr. Lyle: That is all right, that can be done if you split the tempering coils up, as you say, into single pipe coils or something of that sort, within reasonable limits. In fact, with the system of humidity control that I recommend, we do not care whether it is within 15 deg. or not entering the washer, 15 deg. is sufficiently close. But it is impossible to control the humidity within reasonable limits by controlling the temperature, because the temperature must be constantly varying. You

cannot control the humidity in your washer by controlling the tempering coil so as to have a constant temperature going into the washer. The temperature is a constantly varying one, and you have no means of getting it uniform. When you do vary it you get the result of turning on or off of one complete section; and in the commercial sizes, the way they are usually built, that is, a narrow Vento or four pipe blast coil, the variation will run I think about 15 deg., which is about as close as you can get.

CCC.

OPEN WINDOWS WITH MECHANICAL VENTILATION.

BY RALPH C. TAGGART.

There has been some discussion of late in regard to the question of ventilation by open windows and certain misstatements have gained considerable publicity. It would appear that the heating fraternity is partly to blame for some of these misconceptions. The advocates of the open-window ventilation usually maintain that ventilation should be by means of the open window and nothing else, while the advocates of ventilating systems often claim that the ventilation should be left entirely to the ventilating systems installed and that the opening of windows should not be allowed. It is claimed that the opening of windows will upset the balance of the ventilating system and make it ineffective. This closed-window rule has been enforced to such an extent that students in some schools have been suspended or expelled from school because of the opening of a window.

The general question will be taken up later on in this paper, but the author may say here that he believes no ventilating system should be installed in which the balance of the system is appreciably affected by the opening of windows. In other words, where the outdoor air is reasonably good and fairly free from dust, etc., a mechanical ventilating system will give as good or better results when used in conjunction with open windows than in any other way, and, further, the engineer who insists upon closed windows is making almost certain the unsatisfactory operation of his apparatus.

Let us first, however, consider one or two fundamental questions in connection with this matter. The first question is what is meant by good ventilation. Some one will answer pure air. But we may ask how we know when we have pure air, and if we are talking to a layman or perhaps to a doctor he may say,

"I can tell pure air the minute I enter a room," and this is the way the air is judged by most people. In other words, pure air is what appeals to the senses as pure or refreshing. Good ventilation does not then for most people mean chemically good air. It means air which makes one feel good.

The ventilating engineer has usually said that air which would pass certain chemical standards was good air, and, while the ventilating engineer of to-day has changed some of the old standards by which air was judged, he is still holding to a chemical test of the air.

To the ordinary man, however, air which makes him feel good or which he judges as good air is air which meets certain physiological requirements or, in other words, air which makes him comfortable. Now these physiological requirements are not the same for two different individuals, and they are not the same for the same individual at different times of the day or on different days. In the case of many individuals considerable variation may be allowed in most of the qualitative conditions of the air without much discomfort, while in other cases persons whom we sometimes call sensitive can stand only very small variations in the air conditions which surround them without feelings of discomfort.

As an illustration the author may cite the case of an able surgeon who on one occasion was well satisfied with the air conditions in one of his hospital wards, while he was very much dissatisfied with the air some two hours later, when a careful examination indicated that the conditions were exactly the same. He himself had, however, in the meantime indulged in some exercise and also eaten a hearty meal, so that undoubtedly a lower temperature or perhaps a lower humidity of the air would have been required to produce in his body the same physiological sensations which he had experienced when he declared some two hours earlier that the air in the hospital ward was very good.

The question of ventilation involves, therefore, a question of comfort to the occupants of a building which cannot be eliminated, and this will be frankly acknowledged by the ventilating engineers when their attention is called to the matter. The best that we can hope to do, therefore, in ventilating a room in which there are many people is to provide healthful air which will as nearly as possible satisfy the physiological requirements of the

average individual. There has been an attempt in theater and auditorium ventilation to arrange the apparatus so that the quantity of air reaching an individual may be varied. The hope, however, of varying the quality of the air which reaches different individuals in a room with many occupants in order to suit individual requirements seems to be beyond the hope of realization at least for the present.

There is one other factor, however, that should be referred to under the head of the comfort of the individual, and that is the amount of comfort or satisfaction that an individual can gain by the impression or belief that he is really comfortable. We all have heard and seen enough of such instances as the change in the position of a thermometer, making people who thought they were cold believe that they are really warm, to know that the influence of an impression as to how they ought to feel is a very real thing to most people. When we, therefore, tell the occupants of a building that the windows cannot be opened we at once create a desire to open the windows and introduce an element which breeds dissatisfaction.

Aside, however, from all imagination, we should allow the occupants of a room some easy means of changing air conditions within the room. No matter how carefully the system is operated, it cannot meet all individual requirements, and if the opening of windows is not allowed, the simplest, and in many cases almost the only easy, means of controlling certain air conditions is removed.

Where the system itself is controlled automatically the author has known of some very unfortunate instances resulting from the rule forbidding the opening of windows. The automatic apparatus only needs to get out of order one day during the year in order to overheat a room and cause discomfort if windows cannot be opened. This often results in a general animosity toward the heating apparatus that is astonishing, although we ourselves might feel as strongly if forced to undergo equal discomfort.

A ventilating system, to be satisfactory, must then have means of individual adjustment to suit the particular needs of the occupants, and almost the only easy way to vary the quality of the air, and often even the temperature, is by opening the windows.

Let us then consider the question of open-window ventilation.

Open-window ventilation in rooms occupied by a number of people does not mean and does not result in ventilation by open windows in cold weather, because in the majority of cases the occupants will not keep the windows open. Open-window ventilation, therefore, when used alone, means practically no ventilation in the colder weather. In hospitals, with patients in beds, there is the best chance for open-window ventilation, and yet the author has been in a number of hospitals where the doctors were advocating open-window ventilation, and in the colder weather everything was shut up tight and there was no ventilation except leakage through cracks that could not be closed.

In private houses, where the occupants are few, leakage through cracks and air entering through windows which can be opened may give a reasonable air supply. In crowded buildings, however, such as schools, etc., open-window ventilation in cold weather usually means no ventilation.

Let us then consider the question of mechanical ventilating systems with warmed air. It is claimed by some that air warmed and then admitted to a room is injured and air so admitted is sometimes styled "canned" air. Perhaps it would be better to call it sterilized air. If the air is properly washed, the amount of dust remaining is very small, and even if it were all burnt up by the few degrees of warming, the decrease in the oxygen content of the air would be negligible. Air in passing through a steam heater need not be warmed to the excessive temperatures often stated. In fact, some writers on ventilation talk of heating air to 300 and 400 deg. by steam. This is manifestly impossible with steam at 212 deg. F. It is also impossible to heat air in a ventilating apparatus as high as 212 deg. with steam at 212 deg., and it is easy, on the other hand, to arrange the apparatus so that practically none of the air is heated above 98 deg., or blood heat, and so that the average temperature of the air is not raised above 60 or 70 deg., or even 50 deg. or lower, if it is so desired.

Many doctors appear to have the idea that ventilating systems must overheat the air. This, of course, is not so. The air entering the room may be as cool as desired. It seems reasonable, however, to say that it should be warmed sufficiently so that the occupants will allow it to be admitted. Otherwise, we have no ventilation in the sense of admitting fresh air.

Let us then consider the question of using open windows in connection with a ventilating system where air is taken from out-of-doors, and where it is washed and blown through suitable ducts to the various rooms of the building. Some engineers maintain that if windows are opened in rooms supplied with air from a fan or blower a large part of the air supplied by the fan will immediately pass to the rooms in which the windows are open, and that the other rooms will not receive their proper proportion of air, or, in other words, it is maintained that the distribution of the air will be seriously interfered with.

Investigation shows that the tendency of air to enter a building through open windows is much greater than the tendency to suck air out from a room through open windows. This is due to two facts: first, a building acts to a considerable extent like a chimney, and, second, the inertia of the air when there is any breeze is more effective in bringing air in through an open window than in sucking air out.

The engineer may say, however, that it is a question of pressure and that with the ventilating system in operation the various rooms are carried under a considerable pressure. This is a mistaken notion with the ordinary ventilating apparatus. With vent or exhaust flues of any reasonable size, plus also the chances for air leakage around the room itself, it will be found in rare instances only in a ventilating apparatus that the pressure in any room is sufficiently above the outdoor pressure so that it may be measured by any except perhaps the most delicate of instruments. The additional flow of air, therefore, is usually very small in a room with open windows, because of any lessening of pressure within the room. In fact, with the air blowing into a room from out-of-doors it will be found that, while the total air admitted to the room is greater with the windows open, the air entering the room from the ventilating apparatus is less, so that more air, rather than less, is left for the other rooms.

Let us assume a room, however, in which considerable pressure is carried within the room itself, although this usually shows a very faulty design in the ventilating equipment. In such a case the opening of windows on a particular day when the wind is most effective in removing air from the room will cause an excess of air to enter the room from the ventilating apparatus. This excess, however, is not so great as might be imagined, espe-

cially if the connections in the branch flues from the main ducts to the individual rooms have some appreciable resistance, as they usually do.

The increase in air supply varies only as the square root of the increased difference of pressure, and if in the original design the branch connections have been slightly choked so as to place the larger part of the duct resistance in these branches, the increase in air discharge into a room with open windows may be made practically negligible. Some may say that this resistance in the branch connections is very undesirable. This is not so if the main ducts are made of proper size so as to minimize the friction within them, and this is desirable, for the main ducts are usually horizontal ducts, and the horizontal ducts should always be large enough to be easily accessible and large enough so that the total friction resistance within the duct system is small. If the friction in the main ducts is small, the friction in the branch connections may also be small and yet large enough so that the friction in the main ducts is negligible in comparison.

How small an increase in duct sizes is required to reduce the friction in ducts is often not appreciated. For the same quantity of air delivered the friction varies inversely as the fifth power of the diameter, so that if the diameter of a duct or pipe is doubled, its friction is reduced to 1-32 of its former value. If the duct is increased in diameter only 50 per cent., the duct whose diameter is two-thirds of the other duct has a friction resistance more than seven and one-half times as great, or if the diameter is increased only one-fourth, the friction resistance is reduced in the ratio of more than three to one.

It has come to be the practice in many cases in ventilating apparatus to reduce the sizes of ducts, etc., to such an extent that many of the horizontal ducts are practically inaccessible and so that the friction resistance in the apparatus results frequently in the closing down of the apparatus because of the power required to operate the fan, especially if connected to a motor taking electric current, which may cost 5 to 10 cents per kilowatt-hour. Main ducts and main branches, therefore, should be made large, while vertical branches should be properly reduced.

If then the windows may be opened even with the ordinary fan system of heating, some one may say that the good air from the ventilating system will escape directly out-of-doors.

Generally speaking, this is not so, and in the special instances where they occur, short circuits from the air inlets of the ventilating apparatus to open windows are usually easily rectified.

Some, however, may say that whereas we get pure washed air from the ventilating apparatus, we get only dusty air from the windows. This is denied by open-window enthusiasts. The truth lies between these two statements. In very dusty localities there may be considerable objection to admitting air directly from out-of-doors without washing or cleaning it, but I believe there are few who will not acknowledge that we get pretty good air in summer through open windows, and if it is good enough for us in the summer it should not be rejected because of similar chemical constituents in the colder weather.

In regard to the question of humidity, the opening of windows for admitting air may change the humidity of the air, but if it renders the room more habitable and comfortable the author sees no reason why it should not be considered an improvement.

In regard to comfort, on the other hand, there is an element of temperature stratification of the air which seems to be stimulating and invigorating to many people. In other words, air at a dead uniform temperature is not so desirable as air in which there are some differences in temperature. This can be carried too far, however, especially with people of sluggish circulation. In so far as it is desirable it can often be obtained very easily by the opening of windows in conjunction with the ventilating system. It can also be obtained without open windows, but usually not nearly so readily.

Open windows used in conjunction with ventilating systems in general, therefore, increase the quantity of fresh air supplied; provide means for admitting cool air; give an additional temperature control, and often furnish an easy method of adding to the possible comfort of occupants. Open windows, therefore, should not in the average case and absolutely cannot in a well-designed ventilating apparatus interfere with the operation of the ventilating system.

DISCUSSION.

Mr. Still: It is my opinion there is not a subject before this Society of greater moment at this time, particularly to the engineer, if not for the public good, than to start an investiga-

tion either among ourselves or to urge it upon physiologists, to determine what is the quality of air necessary for the welfare of the human being. There are none among them who has any sound opinion on the subject. The fact of the matter is, the only method we have now for determining the quality of air is by the measurement of the carbon dioxide in the air, which has been very conclusively proven is not an exact or satisfactory measurement at all.

In early April I was invited to visit the University of Minnesota, where Professor Bass has equipped a room in one of the Public Schools, located in one of the worst districts of the town, considering the class of children who attend it. They are mostly made up of "river rats" from the lowlands; they are generally very unclean and there has been more complaint about that particular school than any other. We loaned them part of the apparatus and the instruments to carry on this work, and others have loaned other parts of it. They have an air washer, temperature and humidity controlling thermostats and humidostats, and every desk in the room has a nozzle so shaped and at such an angle that each pupil, no matter what his position, whether sitting back in his chair or leaning over his desk, is directly in the flow of fresh air. Unfortunately, the apparatus was not completed in time, so nothing can be done this year. Professor Bass has no hobbies nor theories to demonstrate in this thing at all. His idea is to invite physiologists to come there. The state is paying for a portion of the expense necessary to carry on the investigations. I might add that he has also put in an ozone machine.

I was recently reading an article which appeared in one of the English engineering papers which shows that they are seriously considering this same problem over there. This article concluded there must be something in the changes in the outside atmosphere, not present in an artificially heated building, which has an effect on the human system that present ventilating systems fail to accomplish. The air is not always of the same constitution out of doors, and it is this change from one condition to another which evidently gives us relief. We know that in our exercises and in our amusements and other habits of life, we get very tired of any one continuous steady element; it becomes monotonous and I think perhaps our whole nervous

system unconsciously is affected in this same way by the uniform conditions prevailing inside our buildings; there is something in this beyond the engineer; it is up to the physiologist. I think we ought to take some action or place ourselves on record in some way to induce physiologists to make an examination into this thing on a very much broader scale than ever has been heretofore attempted. We need just such assistance and then we will have a standard and know how to proceed. But as this thing is going on, with a lot of doctors saying one thing and another lot saying something else, the ultimate result will be, there won't be any ventilating business for us, if it all goes to open windows. It seems absurd, on the face of it, that the doctors should take such a stand; they will advocate the open window for a well and healthy individual, and yet if you try to get a doctor to open a window in an operating room he will have a fit; he would not attempt to carry on an operation there because the dust and dirt would blow in and would get into the wounds. I think the case of a patient in whom certain cuts or incisions have been made and is thus exposed to bacteria is no more critical than the constant exposure of the mucous membranes of other parts of our bodies. Some people have a very low resisting quality, either sick or well, whereas other people can throw off most anything; we have to take care of both kinds.

I think it is a very important proposition which confronts us, and I hope the Society will give more than passing attention to it.

A full description of this plant that Professor Bass put in was in a recent issue of the "Metal Worker, Plumber and Steam Fitter."

Chairman Hale: Those who were at the annual meeting in January will remember the heated discussion on the floor on this very subject, mostly between the physiologists; and they have not decided as yet exactly what standard they are going to set up for our consideration. As Mr. Still says, it is a very serious question, and contrary to Mr. Armstrong's suggestion here, it seems to the Chair that it would be unwise for us to make any expression for the public press or for any one's use hereafter unless it is very carefully considered.

My attention has been called to an extract from a report that

came out in one of the papers. In substance it is the same as this report, although there are a few peculiar features about it that you may be interested in. Do you wish to hear it?

Mr. Davis: Inasmuch as I understand the report of that committee is one that will be very important, I think that our Board of Governors should consider the report very carefully, and then if it is correctly printed take means to give it the greatest publicity possible throughout the country.

Chairman Hale: You mean the final report to be made?

Mr. Davis: The report made by the Armstrong Committee. That report, as I understand it, will deal with the question of the ventilation of schools very thoroughly and will put at rest some of these reports such as have been read and which are inaccurate and wrong, and we want to stop that, and the only way that we can do it will be to give publicity to this report of the Armstrong Committee, provided it is correct.

Chairman Hale: Does the Chair understand that you approve of that method recommended by the Armstrong Committee?

Mr. Davis: No, we don't know what it will be.

Chairman Hale: Accepting the report as we have it in abstract.

Mr. Davis: Yes, if the Council approves it and it is right then it should be given publicity.

Chairman Hale: I think it should be left to the Board of Governors to pass upon that matter. The Chair believes it should come before the Society.

Mr. Davis: That will be next January.

Chairman Hale: It is quite an important matter, Mr. Davis.

Mr. Mackay: Would it not be well to have that report when available turned over to our Committee on School Room Ventilation and let them bring it in at the January meeting as part of their report?

Chairman Hale: And in case there is anything in that report or their decision after seeing the report that requires definite action to protect the Society, it is left to the Board of Governors to act as Mr. Davis suggests?

Mr. Stannard: I want to say that Dr. Evans and the Health Commission in Chicago have been making for the past year and a half very exhaustive tests in regard to what is best for the

pupils. They have a room in the normal school set aside for that purpose and they keep a chart of every detail, how it affects the scholars, how it affects their studies, from a human standpoint, you might say. I would suggest that the Committee on School Room Ventilation that Mr. Whitten has just spoken of get in touch with Dr. Evans and that committee as well and embody it in their report.

Mr. Capron: Dr. Shepard, who has had the matter in charge, I believe, has a very fine paper to present at the annual meeting, giving all those reports.

Chairman Hale: That will be very complete.

Mr. Whitten: I will say in reply to Mr. Stannard that our committee is already in touch with Dr. Evans, and not only with Dr. Evans but with several other people who are making similar investigations, and we are endeavoring to get all the information we can from various parts of the country.

The question is not only a physiological question but largely a psychological one, largely a question of imagination as to what is good and what is bad ventilation. That feature was brought out in a conference between a committee of this Society on school ventilation and a committee of the American Society of School Hygiene, in which the doctors and scientists composing the school hygiene committee expressed the unanimous opinion that mechanical ventilation as now practiced by engineers was, in the main, right and desirable, that there were certain features about it which they themselves frankly admitted they did not understand, such as for instance, the most desirable optimum temperatures, optimum relative humidity and the desirability of changes in temperature.

Contrary to the experience of the author regarding the tendency of air to enter a building through open windows rather than to leave it, a long series of observations and experiments, covering a period of five or six years, has shown me that that statement is not true, that, given an independent air supply to a building other than the windows or walls, and with the wind blowing about the building, a greater volume of air will go out of the building than will come in, due, among other reasons, to the expansion of the warm air in the building itself. If there is 50 deg. difference between outdoors and indoors, an artificial plenum is set up and the bad air expands equally in all direc-

tions, being rarefied and seeking, by the laws of physics, to reach air of a similar density, it withstands to a considerable degree the incoming of the cold air. On the sheltered side of a building, there will be, instead of a pressure, a condition which might be called, and is called by the English investigators, a non-pressure, which superinduces the outflow of air, in addition to its natural tendency from expansion. In one case I remember, with a 15-mile wind blowing, the comparative air flow in the duct on the exposed side of the building would be represented by 4 for the inlet and by 7 for the outlet, whereas a comparison of similar ducts in rooms on the sheltered side would show the inlet represented by 8 and the outlet by 3. That might be called an average comparison.

Another thing is that the outflow from the sheltered side of a building or the movement of air within the rooms, is very largely, almost entirely above the breathing level. The warmest air is introduced several feet above the floor. The window sills are several feet above the floor. The air flow is stratified across the room and out of the windows. There is a more or less stagnated condition induced at the bottom of the room near the floor and that produces what might be called a muddy bottom. CO_2 tests taken in this room have shown a large proportion of CO_2 near the floor or up to 2 or 3 ft. above the floor, above the breathing level of the children when seated, in comparison with that in the rooms on the exposed side.

Mr. Lyle: I notice on page 468 this statement made: "In very dusty localities there may be considerable objection to admitting air directly from out of doors without washing or cleaning it, but I believe there are few who will not acknowledge that we get pretty good air in summer through open windows, and if it is good enough for us in the summer it should not be rejected because of similar chemical constituents in the colder weather."

I just want to state an instance that I experienced in New York, where a silk mill, turning out fine silk ribbons, is able to run throughout the summer with the windows open without any trouble from the dirt and dust; and when cold weather comes on in the fall and the people start cooking with their furnaces and things of that sort they have trouble and they have to shut up the place tight, fasten the windows and put in air washers, but in the summer time they throw the windows

wide open. There is a difference in the amount of dirt in outside air in summer and in winter.

There is also another thing. I personally had an experience with a washer where we had a complaint of deterioration. On making examination we found strong traces of sulphuric acid. The water they were using was analyzed and found to be perfectly good, absolutely no trace; but there was sufficient sulphur being taken out of the smoke in the surrounding atmosphere to charge the water rather heavily with sulphuric acid during a week's run. The washer was only cleaned out once a week and of course there was a certain amount of evaporation, and the water, continually flowing in and out, got stronger as the week went along. There was a great deal more trouble of that kind in the winter than in summer, on account of the increased fires we have in our stoves. And those are two things I think the author has not recognized.

Mr. Williams: I simply wish to say I have a sincere admiration for the man who wrote this paper. Evidently he has been bumped good and hard. He ought to be commended for sending such an able article to this Society.

I think, however, a great deal of this window opening business has arisen from the old system of gravity ventilation. Now there is no question that, if you open your windows in a gravity system, the ventilation is immediately retarded. The stacks will not pull as well and they become dead at times. And I have also found this condition true sometimes in fan systems of ventilation; for when you open windows your stack immediately loses in draft power and you do not have as good ventilating results out through that stack as when the windows and doors are kept closed.

Like Mr. Lewis, I am somewhat of a crank on double fan systems of ventilation. I do not care who calls me that as long as I get the results. I am going to give you a little experiment in my line of practice. I want to say to you that opening of windows and doors has very little effect where a double fan system is used. Many a time I have placed my air meter on a windowsill and opened the window wide and when the wind pressure was not too great the air meter would not turn. Now, I have made that experiment so frequently that I cannot be mistaken. In my practice I have almost wholly

used the double fan system; and yet one of the difficulties that I have had with my own men was that they would tell teachers, "You must not open the windows." I have frequently had to correct this by telling them to "Throw open your windows and doors; I don't care. It doesn't affect the system." Neither does it appreciably; but it does in a gravity system and it does in a single fan system. The frequent tests which I have made with air meters convince me that I cannot be mistaken in reference to this statement.

However, as engineers we cannot deny the fact that no matter how well we ventilate a room there is a wholesomeness in the outside air that we do not find inside—I have had rooms where by chemical tests and analysis the air showed exactly the same amount of carbonic acid or dioxide in the air in the room as there was on the outside; and many a test I have made which did not show over half a part increase in ten thousand on the inside, and whereas our present basis allows eight; and yet when you walk out from such a perfectly ventilated room and go into the outer atmosphere there is a wholesomeness in that atmosphere that you do not find inside. Now what is lacking? That is something that it does seem to me we ought to devote our attention to, and I am reaching the conclusion more rapidly every day that it is the lack of oxygen in the amount of air that you take into your lungs as between heated and cold air. I believe that the time is coming, in fact it has come to a certain extent, when we are to reoxygenize that air after it is heated, and do it automatically; and then I think this whole question will die out; because I believe the lack of oxygen is at the bottom of it. This has been done in the tunnels of London already.

Mr. Ralph C. Taggart: I am very glad that my paper has stirred up some discussion, and I am glad to hear from those whose opinions differ from my own. In general, there does not seem to me to have been any great differences of opinion except in a few cases and most of these, I believe, are due to a misconception of one or two simple statements. Mr. Whitten takes exception to my statement:

"Investigation shows that the tendency of the air to enter a building is much greater than the tendency to suck air out from a room through open windows."

This statement refers to the question of pressures. Now air blowing directly against the side of a building will create a greater plus pressure than the minus pressure that will be found on the opposite side of the building. When to this we add the suction effect or chimney effect of the building itself, which increases the effect of the plus pressure on the windward side of the building and decreases the effect of the minus pressure on the leeward side of the building, it is found that the total plus pressure on the windward side of the ordinary building even at varying angles will exceed the total minus pressure. The plus and the minus pressures must be considered in relation to the general pressure which would exist if the wind were not blowing. In parenthesis I may say it is better to use such a term as minus pressure rather than non-pressure. Non-pressure used in this way is fundamentally erroneous in its derivation. This question of the tendency of air to enter or leave a building, or this question of pressure, is not, however, essential to the argument, and this may perhaps be made plain by considering the question of the quantities of air.

If, then, we consider quantities of air, the total quantity entering and leaving a building must (except for momentary differences) at all times be the same. If we consider volumes also, the total volume entering and the total volume leaving a building must be the same, except for small and practically negligible differences due to the small increase in the volume of the heated air.

The reason Mr. Whitten arrives at such differences in volumes on the windward and leeward sides of a building is simply because he only considers a part of the air entering or leaving a room and neglects another part. He misses the important and principal point of the argument. The important question in the ordinary building is not how much air passes through the registers, but how much air do the rooms and do the occupants of the building receive; and in considering the air going into or out from a room we must not talk about a part of the air supply as if it were the whole.

Mr. Whitten says, "that, given an independent air supply to a building other than walls and windows and with the wind blowing about the building, a greater volume will go out of the building than will come in." This, of course, is impossible

if all points at which the air enters and leaves a building are considered, except in so far as the air expands a little by being heated. Mr. Whitten reaches his conclusion simply because in the particular case he considers he neglects the air which the fan brings into the building. It is, of course, apparent that the same total quantity of air must enter a building as that which leaves it. The case he cites as an average one seems at first to show a big difference in the air supplied to the various rooms in the building, but when we look at it more carefully it shows that there is practically no difference at all. As a matter of fact, Mr. Whitten's own figures prove that the rooms on the windward side and the leeward side of the building receive practically the same quantity of air. He says, for instance, that in one case "the comparative flow of the duct on the exposed side of the building would be represented by 4 for the inlet and by 7 for the outlet; whereas a comparison of similar ducts in rooms on the sheltered side the flow would be represented by 8 and the outlet by 3."

In the first case the room was apparently getting a quantity of air represented by 7, as this much was leaving through the vent outlet, and of this 7 a part represented by 4 came from the air inlet flue and a part represented by 3 must have come from out-of-doors.

In the second case, the room was receiving a quantity of air represented by 8, and of the 8 a part represented by 3 left through the vent outlet and a part represented by 5 must have left through the windows. Each room, therefore, received about the same quantity of air, the ratio being 7 to 8, and if we consider the difference in volume due to differences in temperature the actual quantities of air for the two rooms would be still more nearly alike, perhaps 7½ to 8. In the case of these rooms more air must have passed through them than would have been the case with all windows tightly sealed, for in each room the number of inlets to the room or the outlets to the room was increased, and hence the friction was correspondingly lessened. This would result in an increase in the total air supply to the room, confirming what I said when I spoke as follows:

"In fact, with the air blowing into a room from out-of-doors it will be found that, while the total air admitted to the room

is greater with the windows open, the air entering the room from the ventilating apparatus is less, so that more air, rather than less, is left for the other rooms."

So we see that even in the cases cited by Mr. Whitten, where apparently no effort had been made to arrange the apparatus for open-window conditions, still the difference in the total air supply to rooms on the windward side, as compared with those on the leeward side, of the building was relatively small with windows open in both cases.

Mr. Whitten asks how short circuits can be rectified. This is a difficult matter to answer in a general way, as there are many cases to be considered. A careful analysis, however, of the flow of the air currents will usually suggest the best means of properly diffusing the air. In many cases diffusers at the air inlets are of great advantage, and the problem is often much simplified if the incoming air currents are at a comparatively low temperature. In some cases, of course, additional air inlets or air outlets must be provided, but in general a reasonable diffusion of air at moderate temperatures can be obtained through relatively few openings if some judgment is used in their location and arrangement. Of course, if the air entering a room is very hot a part of it will in some cases pass directly out through open windows if the openings are high up. It is desirable, however, and practically essential in good ventilation, not to have the entering air at a high temperature, and where the air is at a moderate temperature it can ordinarily be diffused so as to get good distribution. Each child in himself, we must also remember, is a small heater, and air discharged from the lungs has an initial tendency to rise, so that even, when we may seem at times to lose something by short circuits, we may get better air around the individual if the air from the individual moves away not to return, as it may do if the air discharge is perhaps relatively high up.

Mr. Still refers to the fact that doctors do not like open windows during operations. This is largely due, however, to the fact that drafts are objectionable on the patient's account and because a wind is likely to disturb material in the operating room. The fact of dirt coming in through windows is not, in most cases, the important reason.

Mr. Still refers to unknown qualities of air, such as fresh-

ness. It is possible, but it does not seem probable that there are important qualities of air that are now unknown, although it is true that the exact effects of many of the known qualities of air have not been altogether determined with reference to varying individuals. It is possible to furnish air that has those qualities which are usually recognized as freshness when all of the air comes through a ventilating apparatus, although the idea of freshness itself varies with different individuals.

Mr. Lyle refers to the fact that there may be more dirt in the air in Summer than in Winter. This is true certainly in some localities. There are other localities, however, where the dust from the dry streets in Summer certainly puts the Summer air at a disadvantage. In each case the dirt in the air should be considered in connection with the opening of windows.

Mr. Williams speaks of the single-fan and the two-fan system. He neglects in his discussion, however, to consider the advantage of the air that does not come from the fans. He misses the main point of the argument. The important question in the average building is not, "Do the registers pass at all times the same amount of air?" The important question ordinarily in regard to open windows with a fan system is, "Do the occupants of the room get as much air with windows open as with the windows closed?" His advocacy of the reoxygenizing of air or adding oxygen to warm air because the oxygen per unit volume of warm air is less than per unit volume of cold air, does not appear to be correct if given any consideration. In the first place, the air that is cold before we breathe it is warmed up and expanded before it reaches the lungs. In the second place, we find that many doctors recommend air with small proportions of oxygen, such as air at a high altitude for example, in order to make people involuntarily breathe deeper and use more of their lungs and not less. In fact, some tuberculosis specialists say that the person with large lungs or, in other words, the person who does not use the lungs which he has, is practically the only person who ever gets tuberculosis, for the parts of the lungs which are not used deteriorate, so that, for a regular diet, adding oxygen to the air does not seem important or desirable except, perhaps, in the case of particular diseases.

CCCI.

HEATING AND VENTILATING THE NORTHWESTERN UNIVERSITY BUILDINGS.*

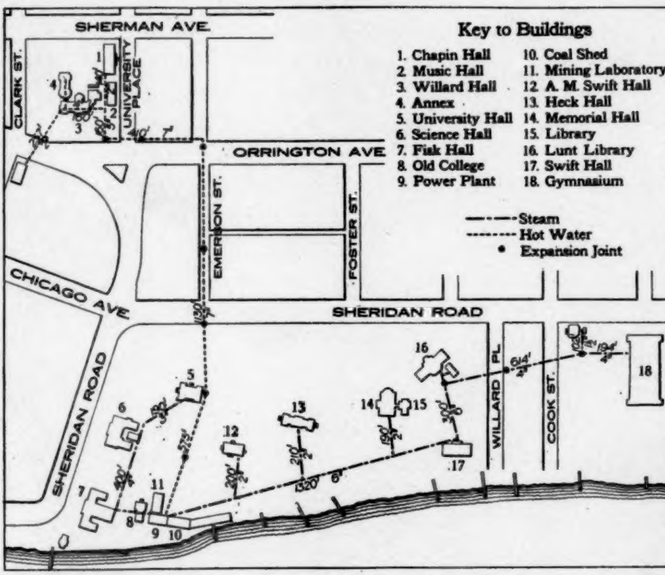
BY J. M. STANNARD.

The heating and ventilating of the Northwestern University buildings, at Evanston, Ill., are accomplished by hot-water forced circulation, and direct and indirect steam plants under both vacuum and gravity methods. The accompanying map shows the various buildings with the method of heating in each, the location of power plant and the size and location of feed mains.

The boiler plant consists of six boilers, four for the generation of steam and two for the reheating of the hot water. Two of the steam boilers are of the horizontal return tubular type, size 72 in. by 18 ft., each rated 150 hp., and having grates 5 x 6 ft. The other two steam boilers are Sterling water-tube boilers, each rated at 250 hp., and having grates 8 x 6 ft. The two boilers for the hot-water heat are of the horizontal return tubular type, size 66 in. x 16 ft., each rated 125 hp., and having a grate surface 5 x 5 ft. The water-tube boilers are equipped with Green traveling chain grates and the four fire tube type are hand fired. The steam boilers are fed with water from a 600-hp. Cochrane open feed-water heater by two duplicate Worthington duplex 6 x 4 x 6-in. pumps. During the more moderate cold weather only one of the hot water boilers is fired for the reheating of water, and two of the boilers are in use for the generation of steam. The steam boilers besides furnishing steam to the radiation also supply steam for the operation of circulating and vacuum pumps and one fan engine, which drives the fan for the induced draft system, as this method is used in the plant rather than natural draft. The fan for induced draft is of the Sturtevant make. It is 72 in. in diameter, and is driven at an average of 280 r.p.m. by a 10-hp. engine, direct connected to it. Coal and ashes are handled by a hand car conveyor.

* Based on a committee report presented to the Illinois Chapter by J. M. Stannard, E. F. Capron, Robert A. Widdicombe and Charles F. Newport.

For the circulation of the hot water there are installed two Marsh single-cylinder double-acting circulating pumps, size 10 x 12 x 12 in., each having a theoretical capacity of 5.87 gal. per single stroke. Both pumps are equipped with Hill pump valves to reduce slippage to a minimum. These pumps are equipped with modern revolution counters so that an accurate record of the water pumped may be kept. There is one large closed heater



MAP OF BUILDINGS, NORTHWESTERN UNIVERSITY, EVANSTON, ILL.

having 396 sq. ft. of heating surface made up of brass tubes. This heater is used in addition to the two hand-fired boilers for reheating the circulation water for the hot-water system. This heater was installed to utilize the exhaust steam from the various pumps and stoker and fan engines. In this manner no exhaust steam whatever is wasted.

Three Marsh vacuum pumps, one size 8 x 12 x 12 in., and the two each 5 x 6½ x 10 in., are installed in the pump room and are used for holding vacuum on the steam-heating return lines and for handling the condensation from this system.

The hot-water system is equipped with a complete set of re-

cording thermometers which show temperatures of outgoing and return water and outside temperature. In addition to the recording instruments there are regular thermometers on the heater and on the return line.

The steam-heating system consists principally of direct radiation supplemented with indirect in three of the larger buildings. The indirect radiation is for ventilating purposes, there being sufficient direct radiation installed for heating only. Steam is generated in the boilers at a pressure of 80 lb., and is reduced in the power plant to 40 lb., at which pressure it is distributed to the various buildings, twelve in number. One to 5 lb. pressure is carried in the direct radiation and blast coils as weather conditions require, and it is maintained by proper size reducing valves located in each individual building. Belvac thermofier float-type vacuum traps are applied to both direct and indirect radiation in two of the buildings, Swift Engineering Hall and Patton Gymnasium.

The pumps at power plant maintain a vacuum averaging about 10 in., which drops to 2 to 3 in. at the point where the returns leave the most distant buildings. The separate return lines are connected into two return mains which lead back to the power plant and are connected through settling chambers to the vacuum pumps in the usual manner. The condensation is then delivered by the vacuum pumps to a receiving tank from which it is delivered by gravity to a feed-water heater and from there is taken by the boiler feed pump and returned to the boilers.

The buildings on the forced circulation hot-water system are heated with direct radiation only. Temperatures and volume of circulation are regulated from the power plant according to the accompanying temperature chart.

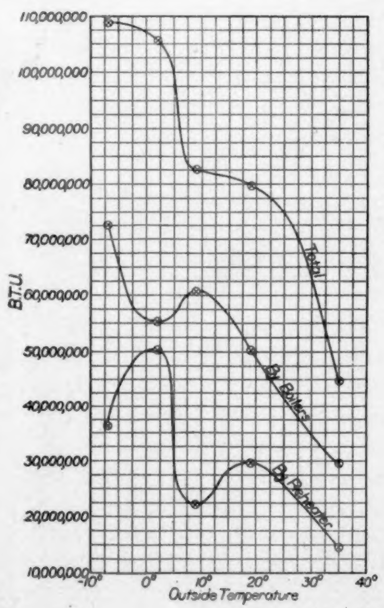
The supply and return mains on the hot-water system are 7 in. in size to a point midway between Emerson Street and University Place; 5 in. from this point to the manhole at the Music Hall, running 4 in. into Willard Hall and 2 in. to Pearson Hall, with a 2-in. line to Chapin Hall. These lines are run in a special conduit, the bottom of which is made of book tile, used for drain, covered with concrete. The pipes are covered with one thickness of high-pressure covering; and a split sewer tile is placed on the top and well cemented. Expansion joints are placed at regular intervals. The expansion of water is taken care of by an ex-

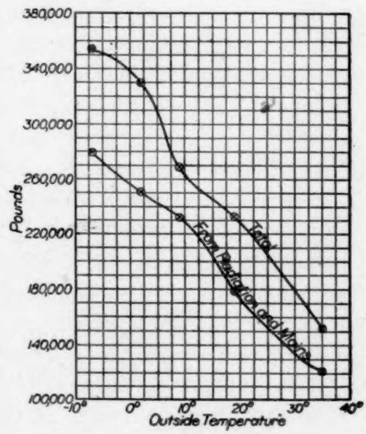
pansion tank placed in University Hall. The total amount of hot-water radiation at the present time is 17,000 sq. ft.

HOT-WATER TEMPERATURES FOR DIFFERENT OUTSIDE CONDITIONS.

OUTSIDE	ORDINARY		HIGH WIND	
TEMP. DEG.	FLOW DEG.	RETURN DEG.	FLOW DEG.	RETURN DEG.
60	115	95	125	100
50	120	100	130	105
40	130	105	140	110
35	135	110	145	115
30	140	115	150	120
25	145	120	155	125
20	152	125	162	130
15	158	130	168	135
10	165	132	175	137
5	173	135	183	140
0	181	140	191	145
−5	190	143	200	148
−10	200	150	210	155
−15	210	155		

For the steam system the size of distributing mains are as follows: One 6-in. main for north buildings extending this size to a point between Swift Engineering Hall and Lunt Library through a 6-ft. concrete tunnel and 4 in. from this point to Patton Gymnasium in a wood conduit. The total load on this north line is equivalent to 36,637 sq. ft. of direct radiation. In addi-





THE CHART IMMEDIATELY ABOVE SHOWS THE CONDENSATION IN THE STEAM SYSTEM IN 24 HOURS.

THE CHART AT THE LEFT GIVES THE AMOUNT OF HEAT ADDED TO THE HOT WATER SYSTEM IN 24 HOURS.

tion this line supplies heat for a hot-water tank for shower baths and the swimming pool, which contains 66,000 gal. of water. A 5-in. line in a brick tunnel carries steam to the south buildings, reducing at Science Hall to 3 in. for University Hall. The total load on this main is equivalent to 18,443 sq. ft. of direct radiation.

Branch lines are taken from these mains to individual buildings. The return lines are run parallel to the feed mains and are 3 in. in size at the power house. One of the interesting features is the fact that the main return line at Patton Gymnasium is approximately 5 ft. below the high part of the tunnel near Swift Engineering Hall. The expansion of both supply and return mains is taken care of by slip expansion joints securely anchored at regular intervals.

Feed mains in tunnel are covered with two thicknesses of 1 in. each of sponge felt covering. Return mains are covered with one thickness of low-pressure covering. Feed mains in the conduit are covered with one thickness of high-pressure covering, and packed together with uncovered return mains in oil shavings in a special wood boxing. The north supply main is dripped at Swift Engineering Hall, Lunt Library and Patton Gymnasium back into return line through traps. The south main is dripped at Fisk Hall and University Hall in a like manner.

All direct radiation in the buildings heated by steam is controlled by the Johnson system of temperature control, and bypass dampers in fan-ventilating systems are similarly controlled. For economical operation it was found by experience absolutely necessary that this temperature control be installed.

VENTILATION.

The foregoing pertains almost entirely to the heating. Owing to the fact that no records are kept on the ventilating system, combined with the fact that limited time has prevented making proper tests, very little will be said in regard to this phase of the subject. Fisk Hall, Engineering Building and Patton Gymnasium are the only buildings equipped with a fan system of ventilation, and this is used intermittently as required. Science Hall, University Hall and Lunt Library are provided with nat-

ural flue ventilation, and in all other buildings no provision whatever is made for the ventilation.

A system of records pertaining to the heating system is kept by the University. It was decided to select five days, the average temperatures of which would be as close as possible to the following: 10 below zero, zero, 10 above and 20 and 35 above. Readings and calculations cover coal burned, amount of condensation, temperatures, etc., for these days, all arranged on a comparative basis. The results are here tabulated.

All temperatures shown, excepting those pertaining to the swimming pool, are averages of 24 readings taken hourly between 10 a. m. and 10 a. m. The pump counters, meter and coal readings are taken once every 24 hrs. at 10 a. m. In some instances, where no meter readings were to be had, as in the cases of steam to the swimming pool, exhaust steam for heating feed-water and the condensation in mains, it was necessary to calculate the amount of condensation to be charged to each and this was done as accurately as possible from the information at hand. The columns relating to heat, efficiencies and cost are the results of calculation based upon the actual records. In figuring the cost columns no account was taken of anything but coal burned. All curves are based on data taken directly from the figures and are submitted only to show graphically some of the more important items.

DISCUSSION.

Mr. Chairman: Can the author explain why there seems to be an inconsistency in this table of hot water temperatures? There is a loss of 20 deg. between the flow and return under ordinary conditions and 25 deg. with a high wind. At 35 deg. outside temperature, there appears to be a greater loss without the wind than there is with it.

Mr. Stannard: This is very likely to be caused by the school-rooms becoming overheated, resulting in the opening of windows. With a high wind velocity the windows would be kept closed.

Chairman Hale: According to the data sheet accompanying this paper, it costs less per square foot to operate a steam system than it does to operate a hot water system. The cost of coal per 1,000 square feet of direct radiation for 24 hours on a given date for steam was $1.16, and on the same date per 1,000 square

feet of direct radiation per 24 hours for hot water was $1.20, a difference of 4 cents in favor of steam.

Mr. Whitten: According to the hot water system data sheet where, on January 5 and 6, the heat delivered to the boilers was something like 112,000,000 B.t.u. with an average outside temperature of 4 deg. below zero, on January 8 and 9, with an average of 2 deg. above, it was 91,000,000 B.t.u. On January 2 and 3, where it was 9 deg. above, the figures are 97,000,000 B.t.u. or about 6,000,000 B.t.u. more. I would like to ask whether the author has any explanation of the conditions that would account for this variation, amounting to 6,000,000 B.t.u. additional required on a day when the outside temperature was 7 degrees higher.

Mr. Stannard: The figures given are not a test of this plant. They were simply taken from their own charts and the readings of the coal burned in the different boilers. I presume that the difference in the comparative cost of the steam and hot water system is largely the result of regulation on the steam system. On the hot water system they simply pumped the water through, governing the temperature at the power plant in some small degree, depending on the outside temperature. The chances are that they were overheating many of the rooms in the building and throwing open the windows.

Mr. Capron: One of the buildings described in the paper is a dormitory, and I presume there are 300 to 400 girls boarding there. They go to class at different times from 8 to 12 o'clock a. m., and when they leave their rooms a great many open the windows for ventilation, and, even in zero weather, if you should go by the building, you would find anywhere from 20 to 40 windows wide open. We have checked up the total cost of operating this plant for the last season and, including all expenses for help, insurance, etc., the total cost runs between 24 and 25 cents per square foot total load; this includes both systems.

CCCII.

TOPICAL DISCUSSIONS.

TOPIC NO. 1.

Upward versus Downward Ventilation.

Mr. Quay: The question of upward or downward ventilation has been discussed from time to time in our meetings and in the various trade papers until it has become threadbare.

Even as applied to theatres the question is not new. The vitiated air being nearest the floor when it is cool would seem to indicate that the vent registers should be placed near the floor to insure satisfactory ventilation.

Whether the upward or downward system is used, there is a great question whether the method of bringing the fresh air in through the floor, under the seats, using the popular "mushroom" distribution, is a satisfactory, sanitary method of ventilation.

Let us analyze the question. First, the mushrooms will not prevent the air from lifting the microbes and other foul matter from the floor and distributing them with the incoming fresh air to the breathing line of the assembly. Second, with this method it is not possible to bring air in at a high enough velocity to give any cooling effect in warm weather, without annoying the occupants, especially the women who are usually attired in light clothing in summer weather. Third, the fresh air brought in by this method, under the seats, is contaminated by being passed over and through the clothing of the occupants, which is not always absolutely clean and free from disease germs.

Fourth, The skirts of the woman often touch and drag on the floor and pick up impurities that are mixed with the incoming air and carried to the breathing line, when this mushroom method of delivery is used.

Fifth, The air is often contaminated with disease from the respiration of those infected.

Sixth, The clothing of the assembly, especially of the women, holds the incoming air under the seats and interferes with its proper distribution and circulation, thereby causing it to become still more impure before reaching the breathing line.

Taking all these things into consideration there seems to be no good reason for using the mushroom method, or any other method of bringing the fresh air into assembly rooms under the seats where it will become so thoroughly contaminated before reaching the breathing line of the audience.

The system should be reversed and the foul air taken out under the seats, and the occupants provided with fresh air from above the breathing line. The outlets should be large enough to remove at least 30 cu. ft. per min. per occupant, without any objectionable draft.

Provision should be made for bringing in the same amount of fresh-tempered air in cool weather and cooled air in warm weather. Provision should also be made for washing and cleaning the incoming air.

I am fully aware that this mushroom method of supplying the fresh air to theatres and auditoriums is quite popular and has been recommended by a number of prominent ventilating engineers. I am convinced, however, that the objections to this system have not been given very careful consideration, or the system would not be in such general use.

We cannot afford, as engineers, to advocate any particular system because of its popularity.

If this system was the only one system that could be satisfactorily used for theatre and auditorium ventilation, there might be some excuse for using it in the face of the objections indicated, but the downward system of bringing air in the proper distance above the audience, and taking it out under the seats referred to, has been extensively used, and the best results have been obtained from its use, so that it is entirely beyond the experimental stage, and overcomes all the objections to the mushroom method referred to.

It is claimed by some that the fresh air cannot be delivered to the main auditorium, especially over the central part, without objectionable drafts. But this is not the case where the exhaust outlets are placed under the seats, that is, reversing the mushroom inlet method, or by placing exhaust registers in the risers

where steps are used in the raised floor, as is often the case in the balconies and galleries.

When the foul air is removed from the central and other parts of the assembly room the fresh air will readily come in to take the place of the foul air displaced.

Chairman Hale: That is a very deep subject for discussion. There are as many different opinions on it, I dare say, as there are people here this afternoon. Many of us have had experience in both directions, probably like both of the methods for certain reasons, and I do not know that there are very many who have actually tested to find the number of bacteria that can be raised from the floor, as Mr. Quay speaks of. It may be possible that tests have been made in theatres where both methods have been used. If there are any members here this afternoon who know of such tests and can give any information on the subject we would be glad to hear from them.

Mr. Lewis: From all the tests that I have heard of where downward ventilation was used in theatres the plants were failures and never have succeeded until they were changed at great expense to upward ventilation. I think there is no question that downward ventilation could be used satisfactorily in rooms in which there was no cooling effect or any heating effect. If you take the people out of the room the air would circulate in an ideal condition and come in and go down and go out, if there were no glass surface or cold wall surface. But that is what we are up against. We have the cold surface against the windows and the air is falling down all the time. We put in radiators to prevent that, then the air is circulating upward in the places in front of the windows and is not circulating downward. The only successful scheme that I have heard of is to provide some method of bringing in the air and taking it out which will not be influenced by the cold windows, by the occupants, and by bringing it in at the floor we do get the benefit of the rising warmth of air caused by each person, which is the important thing.

Regarding the mushroom type, there are lots of ways of getting air into the room without using the mushroom. It is possible to blow air directly at the people if it is blown slow enough. The proper way to ventilate is to blow air right at the people and remove the foul air. I subscribe to the upward way everywhere I can get it.

Chairman Hale: There were two theatres in the west, one in Chicago and one in Milwaukee, that I had more or less to do with some years ago, and we designed apparatus on the upward ventilation method, making a plenum chamber of the entire space beneath the parquet, and putting 3-in. tubes up through the floor under each seat, with not a mushroom over the top, but a butterfly valve that could be so controlled as to govern the volume of air and thus equalize it all over the room. We took out our foul air underneath the balconies up through the ceiling and swept the foul air away from the people up through their clothing across the balconies and to the very top peak of the building. Remarks have often been made of the excellent ventilation of those two theatres. The comfort and the general feeling of satisfaction is much more pronounced there than in many other theatres that have the old type of ventilation, of driving the air out from the walls toward the seats and removing the foul air down through floor registers.

Mr. Quay: In starting this question I said I was not discussing the question of upward or downward ventilation but discussing the question of bringing air in under the seat.

Chairman Hale: And deflecting it down to the floor again?

Mr. Quay: Yes. And that seems to be a popular method. One of the finest auditoriums in the country is being constructed now and that method is being used; and I would like to have some of our members explain the advantages, if there are any, of bringing air in under the seats, even where they use the mushrooms. You cannot bring it in at high enough velocity to give any cooling effect unless you muffle the current. When you bring the air into an auditorium filled with people by this method and pass the air around the occupants, over their clothing and over their persons it becomes contaminated before reaching the breathing line. I am not objecting to the upward ventilation, but to bringing the air in under those conditions and then calling it fresh air when it comes to the breathing line. This is not imaginary. It is a misnomer to call this fresh air after it is contaminated in the manner indicated. I used that same system in the New Amsterdam Theatre in New York under protest, because the owner and architect insisted on using it, but that does not answer this question or the objections to the use of this mushroom method. As far as cooling is concerned,

you cannot bring air in at high enough velocity to get any results. It is not a question of cool air, but of the fan effect; you will not get any movement of air on the face—and that is where you generally fan yourself—with this system when the air has to come in under the seats and pass over the clothing, etc., and in addition to this it is also held in under the seat, under the clothing of the occupants, and prevented from being distributed and brought to the breathing line. If those are not imaginary objections, have any tests been made to show the condition of the air after being mistreated in the way referred to?

Chairman Hale: As Mr. Lewis has stated, the claim is that the greatest danger is the housing of the impure air about the body, rather than taking the foul air into the lungs. The greater danger is there; and if a system of ventilation can be provided that will remove that aerial blanket, you have accomplished a great deal more than if you have simply purified the air that the people breathe.

Mr. Quay: I meant to include that also, the foul air being held there instead of being distributed and removed.

Secretary Macon: If I understand it, Mr. Quay, you are really looking for an opportunity for some one to say that he does not approve of the mushroom type of distributing air by the upward system; do you, or do you not mean that if some other method were provided for bringing the air in without using an inlet which forces the same air down toward the floor line, you would not have any possible objection to it?

Mr. Quay: No, I did not mean that; I object to the mushroom, and also to the method of bringing the air in under the seats by any other method by which the air is held there by the clothing and not properly distributed, not circulated quick enough, it is held there until it becomes contaminated; whether that is the right system, compared with bringing fresh air in above, without objectionable draft to a person, and then drawing it out under the seats—reversing the system.

Chairman Hale: It seems to the Chair that if means were not provided for introducing that air at that point the air that was there about the clothing would become more contaminated and would sooner or later rise up in the breathing zone and would be more dangerous than if you had your air introduced at that point and carrying up the foul air.

Mr. Quay: I would go further than that, by reversing the system and drawing the air out under the seats—I do not mean that you could draw it all out there, but as a general scheme for ventilating the auditorium—removing the air before it became contaminated with fresh air, and the fresh air will come in to fill its place; there being a slight suction there, a partial vacuum, if you please, and the fresh air will be distributed through the audience, so they will have fresh air to breathe; the foul air is being removed through the ducts under the seats.

Mr. Chapman: It occurs to me that a system could be devised to meet the objection of Mr. Quay. The fresh air could be supplied through individual ducts run up the back of each seat and supply the air to the person in the seat directly in the rear, at about the breathing line. The vitiated air could be taken out of the room partly at the floor line and partly at the ceiling line, arranged so, that, say, one-third of the air would be drawn out through mushroom heads under the individual seats and the larger part of the vitiated air (the remaining two-thirds) would be drawn off near the ceiling of the room.

Mr. Williams: I believe that, in a certain way, in one of the churches that we had, we solved the question to the entire satisfaction of everybody; and I am a little doubtful whether it is just absolutely necessary to put as many openings as they do to ventilate a theatre properly. Of course, the greater distribution you start out with the better the ventilation ought to be. In the case I have in mind we brought our air up through the floor on the inside of the pew ends, and then put in a register so as to be in harmony with the pew ends. The air was forced through this register into the aisles; and I never heard one word of complaint. We never used any cooling device at that, and it was a rare thing in that church that they had to open doors and windows even in the summer time. But we threw in a large amount of air. I believe in a large amount of air, not at high velocities, because that will surely give you colds, but in a large amount of air at a very slow velocity. Where you have enough aisles and rows of seats, I believe this the preferable way of taking care of the ventilation of such buildings; but I doubt very much whether the objection raised to mushroom ventilators is not far fetched, for the reason that air follows the lines of the least resistance in an opera house the same as any other

building, and I doubt whether you are not going to get an upward flow of air notwithstanding ladies' dresses.

TOPIC NO. 2.

Motion Picture Theatre Ventilation.

Mr. J. W. H. Myrick: The fireproof operating booth should be ventilated by a fan, as per the Massachusetts standard, but the house should never use the downward system, as this is impractical in any theater, church, hall or place of public gathering with over a sixteen-foot stud. I have seen a number of theatres with the outlet under the stage, drawing against the natural laws; the odors of the gallery are mingled with the perfumes of the orchestra and when the air currents are forced in this direction you naturally kill the acoustic properties. The vent should be from the ceiling or rear of the house, always, and the inlets along the sides near the stage or a plenum chamber under and between the seats according to the location and seating capacity of the house.

Many small houses are bothered with the noise of a fan, whereas some good exhaust heads on the roof drawing from the ceiling grilles, directly connected with them, and a direct-indirect inlet would be far better than what you now find in some houses.

The loss of heat is not a serious matter, for in most places with a good size audience, if you have the temperature at 60 deg. before the show starts, the people seated close together will produce much heat.

ANDREW HARVEY.

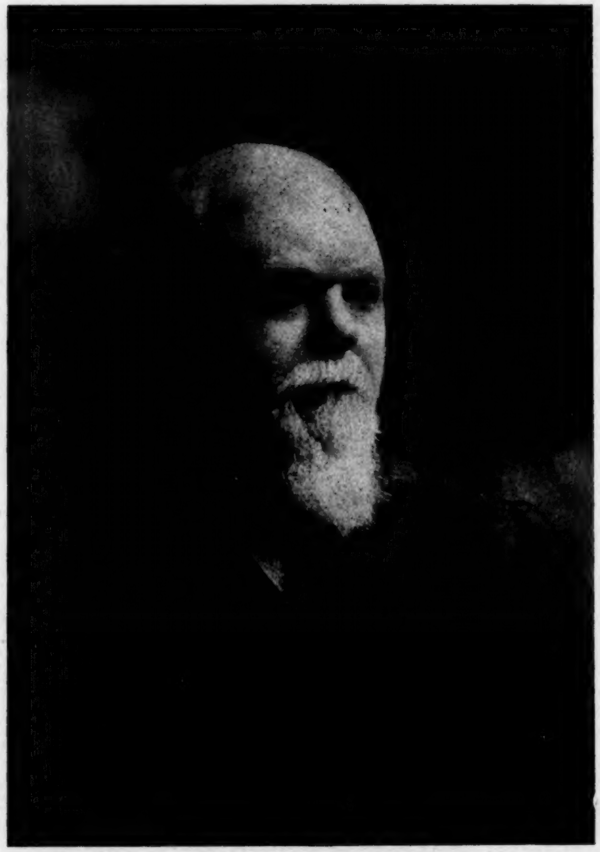
When Andrew Harvey, whose likeness is reproduced on the opposite page, passed to his rest on October 9, 1912, the Society experienced the second inroad into its roster of past presidents. From the time of his election to membership in 1896 until the late stages of his illness which proved fatal, he manifested a keen interest in the work and welfare of the Society. He was stricken with illness earlier in the year and although forewarned of the sad event, his many friends and fellow members learned of his death with sincere sorrow. In his death, the Society lost a member who had served it faithfully and efficiently in an official capacity for several terms.

He held the privilege of attending the annual meetings at which he was a regular attendant as one of the greatest pleasures and regarded them as valuable opportunities to gain instruction. Nor was he content to receive only. Filled with enthusiasm for the progress of the Society, he was always in the front rank in all progressive movements. He was held in high esteem by the many members who had the good fortune to enjoy his acquaintance and friendship and was generally esteemed as a man of unimpeachable character and noble aspirations.

Mr. Harvey was born in Glasgow, Scotland, on March 26, 1843, and came with his parents to America at the age of seven. After remaining three years in New York, his parents settled in Detroit, in which city he received his education. Part of his early life was spent on the lake boats as engineer. After serving apprenticeship he became a partner with his father, who in 1855 established a foundry and machine shop, soon thereafter adding to those branches of his business the installing of steam and hot-water heating systems. The business was thereupon conducted under the name of Andrew Harvey & Son. On the death of his father, the corporate name of the business was changed to the A. Harvey's Sons Manufacturing Co., Ltd., of which Mr. Harvey became president, which office he held up to the time of his death.

Perceiving that the installation of heating systems was destined to become an important branch of the business, Mr. Harvey early devoted himself to a study of the problems of heating and ventilation. Under his direction some of the largest steam heating plants in the United States, including a number of university, college, school and Government buildings were installed. With his long experience in steam heating problems, he was able through his company to place on the market a number of steam specialties, and the business in this department soon grew so that the installing of heating and ventilating systems was eliminated.

Mr. Harvey in 1901–1902 served the Society as its second vice-president; in 1902–1903 as its first vice-president and was then elected president at the annual meeting in 1904. He also served the Society as a member of its council and on various committees. When it was finally decided to hold the semi-annual meeting of the Society for 1912 in Detroit, Mr. Harvey was made an honorary member of the entertainment committee, but owing to the illness which later resulted in his death, he was unable to participate in the preparations for the convention and could not attend any of the sessions. At that meeting a committee was appointed to call on Mr. Harvey to convey the respects of the Society to him.



ANDREW HARVEY

In Memoriam.

L. H. Hart, New York	Sept. 1894	Jan. 26, 1897
James W. Gifford, Attleboro, Mass	Jan. 1898	July 26, 1899
William McMannis, New York	Sept. 1894	Jan. 19, 1901
Charles F. Tay, San Francisco, Cal	Jan. 1896	Sept. 8, 1901
Arthur H. Fowler, Philadelphia, Pa	Jan. 1897	June 3, 1903
Stephen G. Clark, New York	Dec. 1902	Feb. 3, 1904
Charles M. Wilkes, Chicago, Ill	Jan. 1897	Jan. 7, 1905
James Curran, New York	Dec. 1901	Oct. 27, 1905
Herbert W. Nowell, New York	June 1904	Mar. 25, 1905
Enoch Rutzler, New York	July 1901	Feb. 29, 1908
Harry J. Ott, Chicago, Ill	Dec. 1906	Sept. 25, 1908
Thomas J. Waters, Chicago, Ill	Sept. 1894	Feb. 25, 1909
Max J. Mulhall, New York	June 1909	July 30, 1909
Walter B. Pelton, Dorchester, Mass	June 1910	Nov. 2, 1910
R. Barnard Talcott, Denver, Colo	June 1899	Dec. 4, 1910
William H. Bryan, St. Louis, Mo	July 1898	Dec. 8, 1910
James R. Wade, St. Louis, Mo	Dec. 1909	Mar. 9, 1911
James Mackay, Chicago, Ill	Sept. 1894	July 17, 1911
Warren S. Johnson, Milwaukee, Wis	Jan. 1906	Dec. 5, 1911
W. C. Bryant, Holton, Kans	Jan. 1901	April 6, 1912
H. A. Joslin, Boston, Mass	Jan. 1896	Oct. 3, 1912
Andrew Harvey, Detroit, Mich	Jan. 1896	Oct. 9, 1912
N. P. Andrus, Brooklyn, N. Y	Sept. 1894	Jan. 13, 1913

REVISED CONSTITUTION AND BY-LAWS THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

CONSTITUTION.

Article 1.

NAME AND OBJECT.

Section 1. The name of this organization shall be The American Society of Heating and Ventilating Engineers.

Its objects shall be the promotion of the arts and sciences connected with Heating and Ventilating in all branches; the maintenance of a high professional standard among its members; the reading, discussion and publication of professional papers which are calculated to advance the science of Heating and Ventilation; and the interchange of experience among members.

Sec. 2. The headquarters of this Society shall be located in the city of New York.

Article 2.

MEETINGS.

Section 1. The annual meeting of the Society shall be held in New York City in January of each year, the exact date to be fixed by the Council sixty days in advance of the meeting. In addition to the annual meeting, a semi-annual meeting may be held during the summer months. The advisability of calling such meeting, and the place of holding the same shall be determined by the Council at least sixty days before the date selected.

Section 2. Fifteen members present, at either the annual

or the semi-annual meeting, shall constitute a quorum to do business.

ARTICLE 3.

MEMBERSHIP.

SECTION 1. This Society shall be composed of members, junior members, associate members, and honorary members.

SEC. 2. An applicant for membership shall be a Heating or Ventilating Engineer or Expert, who has been professionally engaged in the business of heating and ventilation for at least five years. Graduation from a school of engineering of recognized repute shall be considered as equivalent to two years of active practice. The applicant must be qualified to design as well as take charge of and direct the construction of heating and ventilating work in the branch which he has made his specialty. Mining, civil, electrical, mechanical, naval, or Government engineers, or architects, who are, in the opinion of the Council, qualified by reason of their experience in designing or superintending the installation of heating and ventilating plants, may also become members.

SEC. 3. An applicant for junior membership must have been actively engaged in the work of heating and ventilating for three years, or be a graduate of a school of engineering of recognized repute.

SEC. 4. An applicant for associate membership must have such knowledge of, or connection with the business of heating and ventilating as to qualify him, in the opinion of the Council, to co-operate with heating and ventilating engineers, in the advancement of professional knowledge.

SEC. 5. Honorary membership shall be conferred only on persons who have rendered such eminent service to the science and art of heating and ventilation as shall entitle them, in the opinion of the Council, to this distinction. The number of honorary members shall not exceed five.

SEC. 6. All members, honorary members, juniors and associates shall be equally entitled to the privileges of membership, excepting that honorary members, juniors and associates shall not be entitled to vote or hold any office in the Society.

ARTICLE 4.

ELECTION OF MEMBERS.

SECTION 1. Every candidate for admission to the Society, except a candidate for honorary membership, must be proposed by at least two members to whom he should be personally known, and his application must be seconded by two other members. The application for membership must be accompanied by a statement in writing by the candidate of his qualifications for membership, including an account of his professional experience, together with an agreement that he will conform to the requirements of membership if elected.

SEC. 2. Honorary members shall be proposed only at annual meetings, and the proposal must have the unanimous indorsement of the full Council before their names are submitted to letter ballot.

SEC. 3. All applications for membership are to be sent to the Secretary, and acted upon by the Council, at its first meeting thereafter. The Secretary shall mail to each member of the Society, in the form of a letter ballot, the names of candidates who are recommended by the Council for election, together with a statement of their qualifications, and the names of their proposers and seconders.

SEC. 4. Any member entitled to vote will prepare his ballot by drawing a line through the name or names of any and all candidates whom he rejects. The ballot is to be enclosed in two envelopes, the inner one to be blank, and the outer one indorsed by the member voting, and returned to the Secretary within thirty days of its date.

SEC. 5. The said blank envelopes shall be opened by the Council at the first meeting after the thirty days have expired, and the candidates elected shall be notified at once, and their names announced at the ensuing meeting of the Society. The names of candidates not elected shall neither be recorded nor announced in the proceedings.

SEC. 6. If adverse votes to the number of two per cent. of the votes cast, but not less than seven votes, shall be cast against any candidate, his election shall be defeated.

SEC. 7. Any person who shall be elected to membership in the Society shall be promptly notified of the fact by the Secretary, and he shall accept such election, subscribe to the rules of the Society, and pay the initiation fee within three months after such notice of election shall have been sent him, or his election shall be void.

SEC. 8. The name of any rejected candidate may, after three months from date of such rejection, again be presented to the Council, and if reconsideration is granted, another ballot shall be ordered, at which negative votes to the number of four per cent. of the votes cast, but not less than twelve votes, shall be required to defeat the candidate.

SEC. 9. Junior members desiring to become full members shall make application to the Council, who shall consider the reasons advanced for the change in membership, and if found satisfactory, a favorable vote of the majority of said Council shall be sufficient to authorize the transfer.

ARTICLE 5.

INITIATION FEES AND DUES.

The initiation fees of members and associates shall be $15.00, payable upon notification of their election. Their annual dues shall be $10.00, payable in January of each year in advance or at the date of their election to membership. Members elected prior to July, in each year, shall pay full dues for that year. Members elected after July 1st shall pay half dues for the year in which they are elected.

The initiation fees for juniors shall be $10.00, and their annual dues $10.00. Junior members promoted to full membership shall pay, upon notification of transfer, an initiation fee of $5.00.

ARTICLE 6.

OFFICERS.

SECTION 1. The affairs of the Society shall be managed by a Council of twelve members, which shall consist of the President

of the Society, two Vice-Presidents, six Managers, the Treasurer and the two surviving past-Presidents who last held the office of President. Four members shall constitute a quorum for the transaction of business. The Secretary may take part in the deliberations of the Council, but shall not have a vote therein.

SEC. 2. The President shall preside at all meetings of the Society, and exercise general supervision over its interests and welfare. He shall also be, by virtue of his office, Chairman of the Council. He shall have power to call special meetings of the Council, if in his judgment the needs of the Society require it, and he shall call special meetings of the Council, when so requested by three members of such Council, or if requested in writing by ten members of the Society. He shall appoint all committees not otherwise provided for in these By-Laws, or by resolutions constituting said committees. He or the First Vice-President shall, with the Treasurer, sign all checks, written contracts or other financial obligations of the Society authorized by the Council, and he shall be ex-officio member of all standing committees.

SEC. 3. In the absence of the President from any meeting of the Society or of the Council, the first or second Vice-President shall be vested with all the powers of the President. In the absence of the President and both Vice-Presidents, the meeting shall elect a temporary presiding officer from the members present; the Secretary calling for a vote.

SEC. 4. The Secretary shall be present at all meetings of the Society and of the Council, and keep the minutes thereof. He shall conduct the routine correspondence, receive all communications addressed to the Society, and present the same to the Society or to the proper officers or committees. He shall issue notices of all meetings, promptly inform committees of their appointment, and officers and new members of their election. He shall keep a complete list of members, with their addresses and dates of election, and shall send a copy thereof annually to each member. He shall render all bills and collect all moneys due the Society, turning the same over to the Treasurer, taking his receipt for the same. He shall have charge of all books, periodicals and drawings and similar property belonging to or loaned to the Society. He shall perform such other duties pertaining to

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his office as shall be imposed upon him by the Society or by the Council, and shall receive a salary to be fixed by the Council. He shall give a bond for the faithful performance of his duties, in such amount as the Council may require; the premium to be paid by the Society.

SEC. 5. The Treasurer shall receive and have charge of all funds of the Society, and shall deposit the same to the credit of the Society in such depository as may be designated by the Council. He shall pay all bills, duly approved, and shall keep book accounts of all his receipts and expenditures, which shall be at all times open to inspection by the Council. He shall present, at each annual meeting of the Society, a written statement showing the receipts and expenditures during the previous year; which statement must be duly audited by an Auditing Committee, to be appointed by the Council. He shall make reports to the Council as to the financial standing of the Society at any time they may call for it, provided not less than three days' notice shall have been given. He shall give bonds for the faithful performance of his duties, in such amount and with such securities as the Council may require; the premium to be paid by the Society.

SEC. 6. The Council at the first meeting after the annual meeting, shall appoint a member of the Society to serve as Secretary of the Society for one year, subject to removal for cause by vote of the Council at any time after one month's written notice has been given him, to show cause why he should not be removed, and he has been heard in his own defence if he so desire. The Secretary shall receive a salary which shall be fixed by the Council at the time of his appointment. The Council shall have the supervision and care of all of the property of the Society, and shall manage and conduct its affairs in accordance with the charter and constitution. They shall hold stated meetings, at least once every two months, the first meeting to be held within ten days after the annual meeting, and special meetings at the written request of three members of the Council or upon the call of the President. They shall present at the first session of the annual meeting of the Society, a general statement of its proceedings during the year and a report of the condition of the Society. They shall fill any vacancies occurring among the of-

ficers of the Society. The Council shall, at least one month before the annual meeting, appoint from the active members of the Society three Auditors to examine and certify the accounts of the Treasurer. No officer of the Society shall be eligible as an Auditor. At the first meeting of the Council after the annual meeting, the President shall also appoint from the membership of the Council the following committees, consisting of three members each, to act under the direction of the Council: Finance, Membership and Publication. The Council may appoint an Executive Committee of three of its members, who shall perform such duties as the Council may determine.

The Finance Committee shall have charge of the financial affairs of the Society, and shall approve in writing all expenditures authorized by the Council.

The Membership Committee shall receive from the Secretary all applications for membership, make rigid inquiry as to the eligibility of candidates, and report to the Council only such as have been approved. In case of disapproval, only the proposers of the applicant shall be notified of such action. The proceedings of this committee shall be private and confidential.

The Publication Committee shall receive and examine all papers for presentation to the Society, and accept such as it may approve. The Committee shall review the papers and discussions which have been presented at the meetings, and shall decide what papers and discussions, or parts of the same, shall be published. It shall publish during each year the transactions of the Society, containing the papers and discussions so approved, and abstracts of the minutes of the Society and of the Council. No members shall publish any papers as having been read before the Society without obtaining the consent of this Committee, and such consent shall not be construed to be an indorsement by the Society of any statements advanced in such papers or publications.

These standing committees shall be guided by such rules and regulations as the Council shall from time to time prescribe.

Article 7.

ELECTION OF OFFICERS.

Section 1. At each annual meeting there shall be elected from among the members by letter ballot as directed in Sections 3, 4 and 5:

A President, to hold office for one year.
A Vice-president, to hold office for two years.
Two Managers, each to hold office for three years.
A Treasurer, to hold office for one year.

The term of all elective offices shall begin on the adjournment of the annual meeting of the Society. Officers shall continue in their respective offices until their successors have been elected and have assumed their offices.

A President, Vice-president or Manager shall not be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

(Temporary Clause.)

At the first election of officers after the adoption of this Constitution two Vice-presidents and six Managers shall be elected, and at the first meeting of the Council after the annual meeting it shall determine by lot which of the Vice-presidents shall serve for one year and which for two years, and which of the Managers shall serve for one, two and three years respectively. A Nominating Committee to nominate the officers to be elected at the first annual meeting shall be elected at the semi-annual meeting. (This clause will be omitted from copies of the Constitution printed after January 1, 1913.)

Section 2. A Nominating Committee, of five members of the Society, not officeholders, shall be elected by ballot at the annual meeting. It shall be the duty of this Nominating Committee to select candidates for the various offices that are to be filled at the next ensuing annual meeting. This Committee shall present to the Secretary, at least sixty days before the day of the annual meeting, the names of candidates for the offices to be filled, first securing the consent of the members selected to stand for the election. Ten or more members of the Society may pre-

sent to the Secretary, over their signatures, the name of any member of the Society as a candidate for any office, provided they do so within sixty days of the annual meeting, and the Secretary shall add such names to the ballot, provided they are not already included in the list of names presented in the formal report of the Nominating Committee. Such names when presented shall be included on the printed ballot, with a special notation that they are presented by members independent of the Nominating Committee's report.

SEC. 3. Upon receipt of the list of nominations the Secretary shall at once prepare ballots with the names of all candidates and forward them to the members, at least thirty days before the date of the annual meeting.

SEC. 4. Each member entitled to vote shall cancel the names of all candidates for whom he does not wish to vote, and return his vote so that it will reach the Secretary before the date of the annual meeting. Any member may write upon his ballot the name of any member for whom he wishes to vote, if such name is not on the printed ballot. The ballot is to be enclosed in two envelopes, the inner one to be blank and the outer one indorsed by the voter. The votes of members in arrears for more than one year's dues shall not be counted.

SEC. 5. The ballots shall be opened, and the result of the vote declared on the first day of the annual meeting by three tellers appointed by the President. The candidates receiving the highest vote for the several offices shall be declared elected, and shall take office at the last session of the annual meeting.

SEC. 6. Whenever, by resignation or otherwise, there shall be a vacancy in any office, the Council shall have the power to fill such office until the next annual election, and in the event of a tie vote at any election of officers of the Society, the Council, by a majority vote, shall decide the tie.

ARTICLE 8.

RESIGNATIONS, EXPULSIONS, ETC.

SECTION 1. Any member whose dues are paid in full may resign at any time. Resignations must be presented in writing,

to the Council, who shall act on them at their first meeting following their receipt.

SEC. 2. Any member whose dues shall remain unpaid for one year shall forfeit the privileges of membership, and if he neglect or refuse to pay his dues within thirty days after notification from the Secretary, his name may be stricken from the roll of members by a majority vote of the Council.

SEC. 3. At the end of each fiscal year, the Secretary shall strike from the roll the names of such members as are in arrears for two years' dues to the Society, and shall report the same to the Society at its next meeting.

SEC. 4. Any member may be expelled for conduct on his part likely, in the opinion of the Society, to endanger its welfare, interests, or character; provided, however, that charges have been made to the Council, by a member of the Society in good standing, and that the Council have, after investigation and opportunity for defence, recommended such expulsion.

SEC. 5. Any person ceasing to be a member of the Society, through resignation or otherwise, shall forfeit all right, title and interest in the property of the Society.

ARTICLE 9.

LOCAL CHAPTERS.

Local chapters of the Society may be formed upon application of ten members in any State or Territory or in any political division of any other country, if the organization of such local chapter will, in the judgment of the Council of this Society, advance the Society's interests.

Upon recommendation of the Council, a charter may be granted by the Society to form such local chapter, which shall be operated and conducted under the control and at the pleasure of this Society; such local chapter shall be governed by the Constitution and By-Laws of this Society in so far as they shall not conflict with the laws of such State, Territory or other country, and by such other local By-Laws as may be adopted by the local chapter and approved by the Council of this Society before becoming operative.

The membership of such chapter shall comprise only members of the different grades in good standing in this Society; any member of any local chapter who shall cease to be a member of this Society shall thereby forfeit all right to membership in such local chapter.

Every such local chapter when formed shall be chartered in the name of the State, section of State, County or City, in which the same shall be located.

Article 10.

SOCIETY'S INDORSEMENT.

Recommendation, indorsement or approval shall not be given to or made for any individual, firm, association or corporation, nor for any scientific, literary, mechanical or engineering production. The opinion of the Society, may, however, be expressed on subjects affecting the public welfare, provided that this opinion does not carry with it the promotion of the interests of any individual, firm, association, or corporation, and provided also that it is endorsed by a three-fourths vote of the members present at an annual or semi-annual meeting and approved by the signatures of a majority of the Council present at the meeting.

Article 11.

AMENDMENTS.

Proposed amendments to this Constitution must be presented in writing at a regular meeting of the Society, signed by at least three members, when if approved by a majority of the members present, the Council shall have copies of the proposed amendment sent to all members, together with the reasons why it is thought desirable by the members presenting it that the changes should be made. The question of its adoption shall be voted upon by a letter ballot in the manner prescribed for election of members.

If two-thirds of the votes cast are in favor of the proposed amendment it shall be adopted.

ARTICLE 12.

BY-LAWS AND RULES.

By-Laws and rules for the further ordering of the affairs of the Society in harmony with this Constitution, may be established and amended by the Council by a two-thirds vote of the members present, written notice of the proposed by-law or rule or amendment having been given at the previous regular meeting of the Council and mailed by the Secretary to each member of the Council at least thirty days in advance of the meeting at which action is to be taken, giving the reason why such by-law, rule and amendment is thought desirable.

BY-LAWS.

ORDER OF BUSINESS.

1. Announcement of a quorum.
2. Report of officers—President, Secretary, Treasurer.
3. Report of the Council.
4. Reports of standing and special committees.
5. Unfinished business.
6. Report of tellers of annual election.
7. New business.
8. Reading of papers and discussions.

PARLIAMENTARY RULES.

In all questions arising at any meeting, involving parliamentary rules not provided for in these By-Laws, "Roberts' Rules of Order" shall be the governing authority.

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